PART II. PALAEONTOLOGY

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CONTENTS

I. FAUNA OF THE UPPER PART OF THE RED DOWNTON FORMATION AND THE LOWER GROUP OF THE DITTON SERIES

UNDER this heading are grouped all the elements found in the zones of *Traquairaspis symondsi*, *Pteraspis leathensis* and *P. crouchi*, since, as Drs. Ball and Dineley have explained in Part I of the paper (pp: 201–202) most elements of the *T. symondsi* Zone pass, although in greatly reduced numbers, into the succeeding zone and, from the systematic viewpoint, may therefore be conveniently dealt with together.

Throughout the text, the heights given are relative to the main " *Psammosteus* " Limestone. The numbers in parentheses refer to registered speciemens in the British Museum (Natural History) collections.

Class AGNATHA

Order HETEROSTRACI

Genus ***KALLOSTRAKON*** Lankester, 1870

Kallostrakon sp.

LOCALITIES AND MATERIAL. Fragments probably of this genus have been found at Foxhole Coppice, Monkhopton (25 ft. below " *Psammosteus* " Limestone) and at Targrove Dingle 6 (100 ft. below " *Psammosteus* " Limestone).

Genus ***TESSERASPIS*** Wills, 1935

Tesseraspis tessellata Wills

Tesseraspis sp.

LOCALITIES AND MATERIAL. Except at the type locality, Earnstrey Brook (Leath 3: 70 ft. below " *Psammosteus* " Limestone), the material is extremely fragmentary, although widely distributed. Specimens have been recorded from the following localities:

Abdon Bridge (140 ft. above " *Psammosteus* " Limestone); Clapgate Cottage Quarry (110 ft. above " *Psammosteus* " Limestone); ? Heath Quarry (300 ft. above " *Psammosteus* " Limestone); Hudwick Dingle 1 (immediately above " *Psammosteus* " Limestone); ? Kidnall Gutter 4 (200 ft. above " *Psammosteus* " Limestone); Little Oxenbold (50 ft. below " *Psammosteus* " Limestone); New Inn 1 (16 ft. below " *Psammosteus* " Limestone); Oak Dingle (125 ft. above " *Psammosteus* " Limestone); Park Barn Quarry (80 ft. above " *Psammosteus* " Limestone); Parlour Coppice (400 ft. above " *Psammosteus* " Limestone); ? Silvington, Waterfall (600 ft. above " *Psammosteus* " Limestone).

The range is from 50 ft. below the " *Psammosteus* " Limestone to 400 ft. (? 600 ft.) above it, the higher records being based on uncertain fragments, possibly in some cases of *Weigeltaspis*.

Genus *CORVASPIS* A. S. Woodward, 1934

Corvaspis kingi A. S. Woodward

Localities and material. Apart from the type-locality, Earnstrey Brook (Leath 3: 70 ft. below "*Psammosteus*" Limestone), the material is very fragmentary. Single fragments of this or a related species have been found at Hudwick Dingle 1 (immediately above "*Psammosteus*" Limestone) and Little Oxenbold (50 ft. below "*Psammosteus*" Limestone). A doubtful specimen is recorded from Jubilee Brook (250 ft. above "*Psammosteus*" Limestone).

The range of this species is from 70 ft. below to ? 250 ft. above the "*Psammosteus*" Limestone.

Genus *ANGLASPIS* Jaekel, 1927

Anglaspis macculloughi (A. S. Woodward)

Localities and material. The only extensive material comes from Earnstrey Brook (Leath 3: 70 ft. below "*Psammosteus*" Limestone), where it is very fine and plentiful, but rare and fragmentary specimens from the following places are almost certainly conspecific: Clapgate Cottage Quarry (110 ft. above "*Psammosteus*" Limestone); Clee St. Margaret (675 ft. above "*Psammosteus*" Limestone); Hudwick Dingle 1 (immediately above "*Psammosteus*" Limestone); Little Oxenbold (50 ft. below "*Psammosteus*" Limestone); Targrove Dingle 1 (18 ft. above "*Psammosteus*" Limestone); New Buildings E/3 (75 ft. below "*Psammosteus*" Limestone); New Inn 2 (75 ft. above "*Psammosteus*" Limestone).

The range of this species in this area is therefore from 75 ft. below to 675 ft above the "*Psammosteus*" Limestone.

Genus *PORASPIS* Kiaer, 1930

Poraspis sp.

Localities and material. All the specimens are small rare fragments of shields. Specimens are recorded from Aston Hill Wood 2 (relationship to "*Psammosteus*" Limestone unknown); Bromdon Dingle Brook (Lower Dittonian); Jubilee Brook 1 (250 ft. above "*Psammosteus*" Limestone); Lye Brook 4 (75 ft. above "*Psammosteus*" Limestone); New Inn 1 (16 ft. below "*Psammosteus*" Limestone); New Inn 2 (75 ft. above "*Psammosteus*" Limestone).

Therefore the local range is from 16 ft. below to 250 ft. above the "*Psammosteus*" Limestone.

Genus *TRAQUAIRASPIS* Kiaer, 1932

Traquairaspis symondsi (Lankester)

Localities and material. Apart from the classical locality of Earnstrey Brook (Leath 3: 70 ft. below "*Psammosteus*" Limestone), about 30 good fragments and a fine dorsal disk (P.31146) from Lye Brook 1 (125 ft. below "*Psammosteus*" Limestone) ; a good ventral plate (P.34345) from Lye Brook 3 (90 ft. below " *Psammosteus* " Limestone) and another (P.30026) from Little Oxenbold (50 ft. below " *Psammosteus* " Limestone), the material consists of small rare fragments : Clapgate Cottage Quarry (110 ft. above " *Psammosteus* " Limestone) ; Hudwick Dingle 1 (immediately above " *Psammosteus* " Limestone) ; Kidnall Gutter 1A (30 ft. above " *Psammosteus* " Limestone) ; Lye Brook 1 (125 ft. below " *Psammosteus* " Limestone) ; New Buildings E/3 (75 ft. below " *Psammosteus* " Limestone) ; New Inn 1 (16 ft. below " *Psammosteus* " Limestone) ; Oak Dingle (125 ft. above " *Psammosteus* " Limestone) ; Sudford Dingle 1 (3 to 4 ft. above " *Psammosteus* " Limestone) ; Targrove Quarry (175 ft. above " *Psammosteus* " Limestone).

The total range in the area is from 125 ft. below to 175 ft. above the " *Psammosteus* " Limestone, but apart from that from Hudwick Dingle 1 and Sudford Dingle 1, where the fossiliferous beds lie just over the " *Psammosteus* " Limestone, the total material from above the " *Psammosteus* " Limestone consists of ten very small fragments ; three from Clapgate Cottage Quarry (110 ft. above) ; one from Oak Dingle (125 ft. above) and six from Targrove Quarry (175 ft. above).

Genus ***PTERASPIS*** Kner, 1847

Subgenus ***PTERASPIS*** typicum

Pteraspis (Pteraspis) rostrata (Agassiz)

LOCALITIES AND MATERIAL. The surviving type-specimen (Agassiz, 1935 : 148, pl. 1*b*, fig. 6) is a small unsatisfactory specimen, 5·2 cm. long as preserved, largely an internal cast. Only the base of the snout is preserved as an impression, and this and the form of the cornua establish the species, but not the variety. The specimen came from Whitbatch, Shropshire, a locality in which several quarries were worked from time to time (about 200 ft. above the " *Psammosteus* " Limestone), and from this area material of *Pteraspis* is rare and *Cephalaspis* is relatively common. The *Pteraspis* material comprises ventral disks 6–7 cm. long (P.43448–51) and an even larger fragment (P.43453), and the posterior end of a shield ; but none is sufficient to indicate the particular form, even if such indirect argument were in the circumstances acceptable.

Only nine or ten other localities in the Clee area have produced rostra to establish the occurrence of the species, and in two cases these are unusually broad. Doubtless much of the material identified merely as *Pteraspis* sp. belongs to *P. rostrata*. Specimens assigned to undetermined forms in addition to those from Whitbach are :

Hudwick Dingle 4. Three rostra and a fragment (175 ft. above " *Psammosteus* " Limestone).

Kidnall Gutter 1. A rostrum (P.34328) and a ridge-scale (P.34327). The rostrum is exceptionally broad. (15 ft. above " *Psammosteus* " Limestone.)

New Buildings E/2. One very broad rostrum (P.34336) which is not, however, very different from a diseased specimen from Guildings Brook (P.16472). (110 ft. above " *Psammosteus* " Limestone.)

Rea Bridge, Ditton Priors. Good rostrum (P.31640). (Not *in situ.*)

Pteraspis (Pteraspis) rostrata var. ***waynensis*** White

(Text-fig. 1)

Jubilee Brook 1. Two rostra with part of orbitals, etc. attached (P.30053, P.30056). The inner anterior borders of the orbitals are concave and the medial extensions meet the pineal plate. The second specimen is 2·7 cm. in length with a maximum breadth of 2·4 cm. (Text-fig. 1). (250 ft. above "*Psammosteus*" Limestone.)

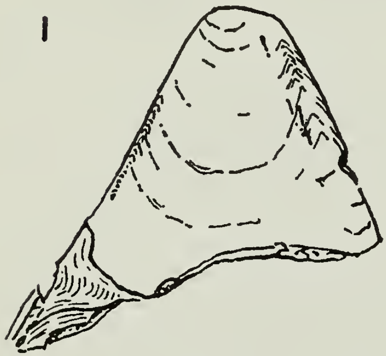


FIG. 1. *Pteraspis* (*Pteraspis*) *rostrata* var. *waynensis* White. Rostrum with part of left orbital plate. Jubilee Brook 1. P.30056. × 1·5.

FIG. 2. *Pteraspis* (*Pteraspis*) *rostrata* var. *trimpleyensis* White. Anterior part of dorsal shield, in impression. Bouldon Ford. P.29955. × 1·5.

Pteraspis (Pteraspis) rostrata var. ***trimpleyensis*** White

(Pl. 34, fig. 5; Pl. 35, figs. 1, 2; Text-fig. 2)

Bouldon Ford. External impression of part of dorsal shield with abnormal sensory canals (P.29955; Text-fig. 2) and other fragments. (50 ft. above "*Psammosteus*" Limestone.)

Oak Dingle. Right half of small dorsal disk (P.33573–74; Pl. 35, fig. 2), rostrum with parts of orbitals (P.33572) and other fragments. (125 ft. above "*Psammosteus*" Limestone.)

Ledwyche Brook. Anterior part of dorsal shield with rather short and broad rostrum, 2 × 1·8 cm. (P.33766; Pl. 35, fig. 1). (50 ft. above "*Psammosteus*" Limestone.)

Targrove Quarry. Greater part of old dorsal shield (45963) and several fragments almost certainly of this form. (175 ft. above "*Psammosteus*" Limestone.)

REMARKS. The ranges shown are as follows :

Pteraspis (*P.*) *rostrata* var. indet. . .	15–200 ft. above " *Psammosteus* " Limestone.
Pteraspis (*P.*) *rostrata* var. *waynensis* .	250 ft. above " *Psammosteus* " Limestone.
Pteraspis (*P.*) *rostrata* var. *trimpleyensis* .	50–175 ft. above " *Psammosteus* " Limestone.

Pteraspis (Pteraspis) dairydinglensis sp. nov.

(Pl. 33 ; Pl. 34, figs. 1–4 ; Pl. 35, figs. 4, 5 ; Pls. 37–41 ; Text-figs. 3–5)

DIAGNOSIS. A typical *Pteraspis* with dorsal shield (without spine) attaining a length of 10 cm., strongly vaulted, with maximum breadth of disk when flattened about four-fifths of its total length ; anterior margin of disk with wide, shallow median indentation and usually rounded antero-lateral corners ; posterior margins long and gently concave when uncrushed; spinal socket about one-third of total length of disk and two-thirds of short compressed triangular spine. Rostrum very short with somewhat angular tip, its length being about one-quarter of the total length of the dorsal shield (without spine) and four-fifths of the distance between the orbital openings. Pre-oral field very short. Pineal plate much wider than long, moderately large and meeting medial extensions of orbital plates except superficially in some old specimens. Branchial plates wide and longitudinally keeled, the flat or slightly concave upper and lower surfaces divided by an acute angle of about 65°. Cornual plates rather narrow, reaching level of centre of ossification of dorsal disk, with concave posterior margin or short hook when abraded.

Ventral disk of usual ovoid shape, much vaulted with rounded or briefly flattened anterior margin and obtuse posterior angle partly overlapped by first ventral ridge-scale.

Ridges of ornamentation $\pm$ 60 per cm., gently rounded in section when fresh. Ornamentation on scales consisting of longitudinal ridges divided by chevron-shaped grooves at intervals slightly increasing to rear, rarely with anterior ridges parallel with front margin.

HOLOTYPE. Imperfect dorsal shield (P.29936 ; Text-fig. 3).

MATERIAL. The material is extensive but although mostly fragmentary is well preserved. In addition to the holotype it includes half-a-dozen imperfect dorsal shields, five ventral disks, a dozen rostra, over 50 other substantial fragments of various parts including a number of oral and circum-oral plates, and more than 100 isolated scales.

LOCALITIES. Bulk of material from Dairy Dingle, East of Neenton ; also from Derrington Rea Bridge, North of Ditton Priors, and a few pieces and scales, almost certainly of this species, from Upton Cresset. The most complete shields come from the Hopton Brook section near Hopton Wafers, and a snout from Hazeley Brook West, outside the area studied.

The position of the Clee localities are: Dairy Dingle (800 ft. above "*Psammosteus*" Limestone); Derrington Rea Bridge (500 ft. above "*Psammosteus*" Limestone); Upton Cresset (400 ft. above "*Psammosteus*" Limestone).

DESCRIPTION. The dorsal shield (P.42366, Pl. 33, fig. 2) from Hopton Brook is by far the most complete specimen and lacks only the left anterior region. Like all the other dorsal shields it is partly flattened and so appears considerably broader

Pteraspis (*Pteraspis*) *dairydinglensis* sp. nov.

FIG. 3. Imperfect dorsal shield. The holotype. Dairy Dingle. P.29936. × 1·2.
FIG. 4. Dorsal spine. Derrington Rea Bridge. P.42005. × 1·6.

than in life. The region around the socket of the dorsal spine is naturally thick and thus reinforced does not crush so readily and still retains much of its original shape, whereas the rostrum is flattened. As preserved the total length, including the socket, is 9·3 cm., the breadth 6·2 cm. flat at the maximum (just in front of the branchial opening) and about 7·2 cm. over the curve.

In this specimen the rostrum is short and is a little less than one-quarter of the length of the shield. It usually appears to be very broad owing to flattening (Pl. 34, figs. 1, 3; Text-fig. 6), and the measurements in various specimens are:

Specimen	Locality	Length (cm.)	Max. breadth over curve (cm.)
P.42366	Hopton Brook	2·3	3·4*
P.42361	,,	2·5	3·2
P.42360	,,	2·0	3·2
P.32249	Derrington	1·9	2·6
P.32248	,,	2·5	3·1
P.29997	Dairy Dingle	2·0	3·0*

* Double half breadth.

The real form of this plate, which is quite high, is only seen in P.42360 of which the maximum breadth when viewed directly is 2·7 cm., 0·5 cm. less than over the curve (Pl. 33, fig. 1).

Isolated rostra or fragments of them are exceptionally common, especially the solid tips, for there is usually a large space above the pre-oral field occupied in life by cartilage. The undersurface of the snout is very like that of *P. rostrata* (Pl. 34, figs. 1*a*, 5), only much shorter, especially in the younger specimens, in one of which (Pl. 34, fig. 2) a very marked median spur is preserved.

There are twelve isolated oral or tooth-plates excellently preserved (P.43709–20; Pl. 37). As in *P. rostrata* (White, 1935 : 408, text-figs. 41–47) they are flat and wide proximally, high and narrow distally.

The median oral plate (or plates) is very short and cut off from the post-oral covers by those on either side (Pl. 37, fig. 1). It consists chiefly of the large head, resembling a triangular arrow-head, which greatly overhangs the smooth inner surface. The neighbouring tooth-plates are longer and curved, but the plates increase in length and become straighter towards the corners of the mouth, and at the same time the heads become smaller. The outer or lower surface is ornamented, so are all the sides of the heads (cf. Stensiö, 1958 : 265). The plates overlapped one another decreasingly outwards, the area of overlap being wide in the middle of the series, but at the sides the lateral face on the outermost plate has an almost vertical contact with the fixed lateral oral plate. All but the short median plate were overlapped proximally by the post-oral covers, and the inner surface, by which each plate was doubtless attached to a cartilaginous framework, is smooth except for a few pores.

The ornamentation of the heads of these plates consists of numerous slightly raised triangles, none of which shows any sign of wear. On the outer surface the dentine ridges are short and transverse, with occasionally a few longitudinal ridges along the overlapped margin. Ventrally the ornament sometimes shows signs of having been rubbed by movement against the post-oral covers (Pl. 37, fig. 10). The smooth basal layer of the inner surface is thin and shows a number of openings for vascular canals.

A careful re-examination of the oral plates of *P. rostrata toombsi* (White, 1935 : 408, text-figs. 41–48) shows that they are in fact similar in shape and disposition to those described here. Neither in that form nor in *P. dairydinglensis* are there any signs of the false upper dentures with which Stensiö (1958 : 350, text-figs. 191A, B, etc.) has invested the pteraspids, and their supposed presence is against all the evidence. In the former species where the plates are all preserved in place as moulds such a feature would certainly be apparent and in the case of the new species, where very delicate plates are preserved as complete entities there is no sign of them ; moreover the tips of the dental plates show no signs whatever of wear, as would be bound to appear if they worked against an upper set. They must have had some degree of movement or the mouth could have opened but relatively little, possibly no more than the areas of overlap indicate ; and since these are unilateral towards the outside, with the largest in the middle and below, the movement must have been towards forming a scoop, that is with the centre pushed forwards relatively to the sides. *Pteraspis* probably fed on organic matter off the bottom in muddy waters, as already suggested (White, 1935 : 412), but the vaulted ventral and dorsal plates clearly indicate that they were free swimming, as the hypocercal tail also shows (Kermack 1943), although not very efficiently so. It is possible that the more strongly vaulted forms such as *P. dairydinglensis* were also surface-feeders, as Harris (1936) has suggested in the case of the more evenly balanced Anaspids. Such forms, which usually appear to be wider and flatter than the others owing to crushing, always have short snouts and therefore small pre-oral fields, and since these are sensory areas connected with food-finding, it is probable that their restriction in size does go with surface-feeding where feeding would be more nearly mechanical or based partly on sight, and where a relatively broader mouth would be useful. The long, broad-snouted pteraspids, like *P.* (*Cymripteraspis*) *leachi* and *P.* (*Rhinopteraspis*) *dunensis*, usually large animals with even smaller pre-oral fields were possibly also surface—or even mid-water feeders living in stronger currents, sometimes under estuarine conditions, but *P.* (*Belgicaspis*) *crouchi* with a narrow typically rounded snout and large pre-oral field was probably again a bottom-feeder in cloudy water, as its frequent association with *P.* (*P.*) *rostrata* indicates. It is perhaps not without significance that only once has *P.* (*P.*) *dairydinglensis* been found with another species, *P.* (*B.*) *crouchi*, and it is possible that the appearance of broad, long-snouted forms in the higher beds is connected with changed environmental conditions. It seems likely that the extreme rarity of pteraspids in the Scotch Lower Old Red Sandstone is due to the lacustrine conditions there prevalent, for these would be less suitable for free-swimming forms like pteraspids with their ability, albeit limited, to live in current-dominated areas, such as rivers and estuaries, than for the wholly bottom-dwelling cephalaspids, whose flat underside and dorsal eyes clearly show their usual method of living on the bottom, preferably of quiet waters.

The dorsal disk has the usual outline, heart-shaped in front and pointed behind. The anterior indentation is wide to accommodate the short, wide pineal plate, and the front corners are rounded. The median length (including spinal socket) of the most complete specimen (Pl. 33, fig. 1) is 6·9 cm., the maximum breadth over the curve, 6 cm. The hinder part of the plate is much vaulted (Pl. 33, fig. 3) and the hinder margin on each side of the spine was in life nearly straight.

The dorsal spine was clearly short and deep (Text-fig. 4; P.32243) but although the specimen figured has little missing, the tip is rubbed and may have been somewhat more pointed.

The orbitals are rather short but wide, with their medial extensions usually in full contact with the very wide and short pineal plate (Pl. 33, figs. 1, 2; Pl. 34, figs. 1, 3, 4).

FIG. 5. *Pteraspis* (*Pteraspis*) *dairydinglensis* sp. nov. Imperfect dorsal shield. Hopton Brook 4. P.42364. × 1·2.

The branchial opening is at about two-thirds of the distance from the anterior margin to the posterior outer corner of the disk, so that the branchial plates are relatively long (Pl. 33, fig. 1). The plates have a very marked keel dividing the almost flat upper and lower surfaces (Pl. 33, figs. 4, 4*a*) which are separated by about 65°. The cornual plate is narrow but increases in width to the rear, ending in a slight flat hook, which is usually rubbed off (Pl. 33, figs. 2, 4, 5).

The ventral disks (Pl. 35, figs. 4, 5) show no special features. They were undoubtedly very convex in life, like the dorsal shield, and consequently appear short and broad when flattened. The transverse front margin is very short and the posterior point blunt with its two sides slightly concave.

Owing to the nature of the matrix, which disintegrates in acetic acid, a very large number of isolated scales were obtained (Pl. 39, figs. 9–25; Pls. 40, 41). Their variation in shape, size and function conforms to the usual pattern in *Pteraspis* (see White, 1935 : 414, 419, pl. 27, text-figs. 51–65; 1950 : 81, text-figs. 10–13) with the several kinds of ridge-scales, flank-scales, double flank-scales and so on. One point not previously observed is the piercing of scales for the continuation of the sensory canals from the carapace on to the hinder part of the body; this can be seen in some seventeen specimens (Pl. 39, figs. 9–25). The canal entered the scale in the anterior overlapped area and left it in the short overlapping margin on the inner surface some distance from the hinder margin. There was no external opening through the scale. This explains why indications of the lateral lines are so rare, even in the complete specimens with tails, which are preserved as external impressions. In these only one shows substantial parts of this system on the squamation, parts of both left and right dorsal lines appearing as infillings of the canals (White, 1935 : 42, text-fig. 64).

There were three pairs of lateral lines, as the dorsal and ventral disks show, a dorsal line on each side of the dorsal ridge-scales, the main dorsal lateral line running low on the upper surface just above the level of the cornua, and a ventro-lateral line just below the level of the cornua and branchial plates. Of the extent of these lines we only know that the dorsal line ran almost to the caudal constriction at least. It is difficult to ascertain to which of these lines the isolated scales belong, in particular, as between the two lateral canals, but the smaller scales, especially the more oblique ones, probably belong to the dorsal line. Nor can one be certain of the distribution of all the ridge-scales. The long scales with little anterior overlap are almost certainly dorsal ridge-scales from the separated anterior series, while the more compressed scale (No. 32) is from the pre-caudal row. The broad flattish scales (P.43621–23) are ventrals, and so are the two very different simply ornamented scales (Pl. 40, figs. 10, 11) characteristic of the anterior ventral ridge- series.

The predominantly diamond-shaped body-scales show a remarkable range in form, and include the usual double scales (Pl. 40, figs. 14–27; Pl. 41).

The ornamentation of the scales is typical of the genus, but varied in detail. In general it resembles that of *P.* (*P.*) *rostrata trimpleyensis*, without anterior ridges parallel with the front margin, and with the chevron-grooves more or less evenly distributed on the body of the scales, except on the ridge-scales. On the anterior ventral ridge-scale they are entirely absent, and on the others the intervals separating them increase rapidly towards the rear. There are, however, a number of flank scales in which the anterior ridges appear in varying numbers and in some they are as numerous as in those of the typical scales of *P.* (*P.*) *rostrata toombsi* (White, 1935, pl. 27). The area of overlap is variable but usually narrow.

A curious feature of these scales in general is the frequency with which the ornamentation is carried over on to the underside at the free posterior end. It suggests that there were considerable pockets of epidermis and that the scales did not lie flat but were raised like spent pine-cones. This is also shown in the American *P. carmani* (Denison, 1960 : 396, fig. 141J) and is probably common to all species.

Like the scales and oral plates, a number of circum-oral plates have been isolated from the matrix, all but one from Dairy Dingle (Pl. 38; Pl. 39, figs. 1–8).

There are five examples of anterior lateral plates (Pl. 38, figs. 4, 5). They are distinguished at once by the branched sensory canal system which consists of a large, short canal near one side with a single smaller branch nearly at right angles to it. The main canal is a segment of the ventral longitudinal canal which runs from the ventral disk through the lateral plates on to the dorsal side of the snout. The plates are wider than long, the smaller one figured being irregularly squarish, the larger almost L-shaped. These two are clearly from opposite sides of the animal, and both show an overlapped projection to one side. The smaller lateral canal opens towards the curved longer margin which is feather-edged with the ornament invading the undersurface. Clearly this must be the free side along the ventral disk and thus, the overlapped projection must be for the fixed lateral oral plate which itself is overlapped along the rest of the contact. There is no branch in this plate to the orbital behind the orbit, so that the infraorbital sensory canal must have been discontinuous.

Four out of seven posterior lateral plates are figured (Pl. 39, figs. 1–4). They are in general considerably longer than wide with the sides roughly parallel. Their distinguishing feature is the single sensory canal, which runs down their length, usually forming a broad ridge on the undersurface. Like all these circum-oral plates, the shape is varied and they tend to fuse to the sides of the shield. One such plate shows that the basal and polygonal layers were completely fused to the shield, but that the outer layer was free (cf. White, 1938, text-figs. 2–4).

The nine fixed lateral oral plates (Pl. 38, figs. 1–3) are roughly triangular, sometimes with the apex truncated, in which case there will have been a smaller triangular plate such as in *P.* (*P.*) *rostrata toombsi* (White, 1935, text-figs. 43, 45). The single canal crosses the plate but probably missed the small anterior plate when separate. The contacts of the larger plate are deep and nearly vertical. This plate sometimes fuses to the oral margin of the rostrum forming a marked " angle préorogoniale " (Pl. 34, fig. 1*a*) such as is said to characterize certain of Stensiö's (1958, text-fig. 139, etc.) forms.

The post-oral covers (Pl. 39, figs. 5–8) are amazingly variable in shape, and the number also must have been variable in order to accommodate such odd shapes, most of which show overlapping sides. All are marked by concentric ornamentation and the absence of sensory canals.

It is interesting to note that none of the lateral plates nor the post-oral covers shows any sign of internal ornamentation other than occasionally at the margin, as in some scales. This is in contrast to the condition described by Stensiö (1958 : 265, text-figs. 140B, 191A, B) on which he bases the presence of his " fente post-orogoniale ".

REMARKS. *P.* (*P.*) *dairydinglensis* in all its known features is just an exaggerated, vaulted, short-snouted edition of *P.* (*P.*) *rostrata* from which it was undoubtedly derived. Isolated fragments of plates or isolated scales would often be difficult or impossible to identify with one species or the other, and this provides a warning in accepting past identifications based on such material.

The vaulted shape, as noted above, suggests that this species may have been a freer swimmer than *P.* (*P.*) *rostrata* and a surface rather than a bottom-feeder.

The range of *P.* (*P.*) *dairydinglensis* is 400 to 800 ft. above the "*Psammosteus*" Limestone; approximating to the upper part of the *crouchi* Zone.

Subgenus ***BELGICASPIS*** Zych, 1931

Pteraspis (Belgicaspis) crouchi Lankester

(Pl. 36, figs. 2–11)

LOCALITIES AND MATERIAL.

Batch Brook. Small imperfect dorsal disk, 3·1 cm. long and about 2 cm. broad, with large pineal indentation (P.33799). Near var. *heightingtonensis*. (800 ft. above "*Psammosteus*" Limestone.)

Clee St. Margaret. Numerous pieces, chiefly fragments. One narrow dorsal disk 4·2 cm. long and 2·4 cm. broad (P.32171). Near var. *heightingtonensis*, but sides not so straight as in holotype. There are seven remarkable rostra, all short and triangular (e.g. P.29833–35, P.32164–66, P.32179; Pl. 36, figs. 6–8). (675 ft. above "*Psammosteus*" Limestone.)

Earnstrey Hall 1. Several fragments including good small normal rostrum and a dorsal spine (P.27067–68) and a normal small rostrum and one broader on same slab (Pl. 36, figs. 4, 5), the measurements being 1·3 × 0·35 cm. and 1·5 × 0·6 cm. respectively. (400 ft. above "*Psammosteus*" limestone.)

Earnstrey Hall 2. Fragment probably of this species. (420 ft. above "*Psammosteus*" Limestone.)

Great Northwood. Fragment probably of this species. (Upper part of lower group.)

Heath Quarry. Small typical rostrum; a very imperfect dorsal disk over 5·5 cm. long and 4·0 cm. wide (P.29847); a good branchial (Pl. 36, fig. 2) about 4·5 cm. long when complete with the undersurface having a maximum breadth of 0·9 cm.; and other fragments. (300 ft. above "*Psammosteus*" Limestone.)

The Hills, Downton. Isolated typical rostrum, and dorsal and ventral disks. (Position uncertain.)

Kidnall Gutter 3. A typical branchial (P.43222) and other fragments. (About 180 ft. above "*Psammosteus*" Limestone.)

Middleton Priors. Six rostra, one ventral disk 7·6 cm. long, etc. (500 ft. above "*Psammosteus*" Limestone.)

New Buildings B. One large dorsal disk 5·5 cm. long and about 4 cm. wide. (Loose block.)

Oldfield, the Lobby. Rostrum etc. (Position uncertain.)

Silvington, Drainage Gully. Typical pieces of disk. (575 ft. above "*Psammosteus*" Limestone.)

Silvington, Waterfall. Very numerous specimens. The dorsal disks range in size from 5·5 × 3·6 cm. (P.29877) through 4·0 × 2·6 cm. (P.29045) down to 2·8 × 2 cm. (P.29881), approaching var. *heightingtonensis* in form. The rostra show a remarkable range in size and shape (Pl. 36, figs. 9–11), the largest

(P.29043) is normal in shape, the middle sizes are triangular (P.29832, P.29041, P.29830) and the smallest are a little longer than wide (P.29823–24, P.29831, P.29042). (About 600 ft. above " *Psammosteus* " Limestone.)

Sudford Dingle 2. Small narrow rostrum (P.34332) and other fragments. (About 170 ft. above " *Psammosteus* " Limestone.)

Targrove Dingle 3. Part of large narrow rostrum (P.43023), etc. (About 250 ft. above " *Psammosteus* " Limestone.)

REMARKS. The known range of this species is very different from that of *P.* (*P.*) *rostrata*, starting at about 170 ft. above the " *Psammosteus* " Limestone it reaches 800 ft., so that in this area, the two species only overlap at the very bottom of its range ; but in fact they have never been taken together in the Clee district, although they certainly occur together elsewhere.

The most interesting feature of this species is the occurrence of very short rostra in several localities. They undoubtedly belong to *P.* (*B.*) *crouchi* and are usually associated with others of normal shape. They all show the single cross-over of the ridges of the ornamentation from the upper to the lower surface typical of this species, which clearly distinguishes them from rostra of nearly similar shape of *P.* (*P.*) *rostrata*. In the latter the ridges form a Z-pattern along the sides (cf. Pl. 35, fig. 1 and Pl. 36, figs. 6–11).

These rostra cannot represent growth-stages, for some of the short and long rostra belonged to animals of comparable size (Pl. 36, figs. 4, 5), and in any case, one rostrum could not develop from another except by complete resorption, of which I have seen no evidence. It is also unlikely that they represent sexual dimorphism, although a similar phenomenon is known in *P.* (*P.*) *rostrata*, for there is considerable variation in the form of the short snouts and there may be gradations between the two types.

The explanation of the phenomenon is probably quite different. *P.* (*B.*) *crouchi* is a very specialized isolated form, particularly in respect of its snout. When typically developed it is unlike that of any other species of *Pteraspis*. The rostrum of *Pteraspis* in the earlier forms, was short and broad, and among such were the ancestors of *P.* (*B.*) *crouchi*. It is probable that the spasmodic occurrence of these unusual stout and broad snouts both in this species and in *P.* (*P.*) *rostrata* is due to a degree of 'atavism' (de Beer, 1951 : 104), possibly brought about by genetic drift in small, relatively isolated populations.

The short snouts have not been found below 400 ft. above the " *Psammosteus* " Limestone, but the amount of material in the lower beds is not significant.

Subgenus ***SIMOPTERASPIS*** White, 1950

This subgenus was founded on *P. leathensis* White (1950 : 76) and also was held to include *P. gosseleti* Leriche, *P. primaeva* Kiaer and *P. vogti* Kiaer, all small short-snouted forms. Of these only in *P. leathensis* (Pl. 35, fig. 3*a*) and *P. primaeva* is the important pre-oral region known and thus the relationships of *P. leathensis* to *P. gosseleti* which Leriche (1924 : 149, footnote) has made the type a subgenus of

Protopteraspis on the supposition that the spine was not separated from the dorsal disk, is uncertain and they are for the time being retained in the subgenera of which they are the respective types.

Pteraspis (Simopteraspis) leathensis White

(Pl. 35, figs. 3, 3*a*)

Localities and material. This species is recorded from eleven localities.

Aston Hill Wood 1. External impression of whole dorsal shield and spine (P.25253). (Loose blocks from unknown level.)

Clapgate Cottage Quarry. Fragment possibly referable to this species (P.37776). (110 ft. above " *Psammosteus* " Limestone.)

Hudwick Dingle 1. Poor fragments, probably of this species. (Immediately overlying " *Psammosteus* " Limestone.)

Hudwick Dingle 3. External impression of anterior half of large dorsal shield (P.42834–35), ventral disk (P.34042), etc. (80 ft. above " *Psammosteus* " Limestone.)

Kidnall Gutter 1a. Typical fragments including part of rostrum (P.43109) and disk (P.43110). (30 ft. above " *Psammosteus* " Limestone.)

Leath 1. The type locality. (Level unknown, but ?Ditton Series, lower group).

Lye Brook 2. Fragments probably of this species. (Position uncertain.)

Lye Brook 4. Imperfect dorsal shield (P.26927), etc. (75 ft. above " *Psammosteus* " Limestone.)

New Inn 1. Over 40 specimens finely preserved, mostly fragmentary, but including fine dorsal shields (P.34120, Pl. 35, fig. 3; P.34076), dorsal spine (P.34256) and ventral disks (P.34851). (16 ft. below " *Psammosteus* " Limestone.)

New Inn 2. A dozen finely preserved typical fragments and scales (P.34518–27, P.43014, (75 ft. above " *Psammosteus* " Limestone.)

Yewtree Dingle. Characteristic ventral disks (e.g. P.26937–38); rostrum (P.26942) and other fragments. (50 ft. above " *Psammosteus* " Limestone.)

Remarks. *P.* (*S.*) *leathensis* ranges from 16 ft. below to 110 ft. above the " *Psammosteus* " Limestone.

Order ANASPIDA

A single scale (P.28665) is recorded from Targrove Dingle 6 (100 ft. below " *Psammosteus* " Limestone).

Order THELODONTI

Thelodont scales have been noted from about 20 localities in the lower group, ranging from Lye Brook 3 (90 ft. below the " *Psammosteus* " Limestone) to Batch Brook and Dairy Dingle (800 ft. above). Almost invariably they are accompanied by Acanthodian scales. It is probable that their presence is universal, and the restricting factor is the ease with which the matrix yields to acid treatment. At the moment insufficient material has been recovered to make a close study worth while.

Order OSTEOSTRACI

Genus *CEPHALASPIS* Agassiz, 1835

Cephalaspis acutirostris Stensiö

LOCALITY. Whitbatch Quarry (about 200 ft. above "*Psammosteus*" Limestone).

Cephalaspis cf. *agassizi* (Lankester)

LOCALITY. Bluck's House (Ditton Series, lower group), centre of shield (P.33752).

Cephalaspis cf. *fletti* Stensiö

LOCALITY. Bluck's House (Ditton Series, lower group), centre of shield (P.33749-50).

Cephalaspis cf. *langi* Stensiö

LOCALITY. Bluck's House (Ditton Series, lower group), a small badly preserved head shield (P.33751) measuring 3·7 cm. across base of cornua, with rounded rostral margin.

Cephalaspis lankesteri Stensiö

LOCALITY. Whitbatch Quarry (about 200 ft. above "*Psammosteus*" Limestone).

Cephalaspis whitbatchensis Stensiö

LOCALITY. Whitbatch Quarry (about 200 ft. above "*Psammosteus*" Limestone).

Cephalaspis whitei Stensiö

LOCALITY. Whitbatch Quarry (about 200 ft. above "*Psammosteus*" Limestone).

Cephalaspis bouldonensis sp. nov.

(Pl. 36, fig. 1 ; Text-fig. 6)

DIAGNOSIS. A *Cephalaspis* of moderate size, with maximum breadth of cephalic shield across top of pectoral sinuses, approx. 7 cm. when complete, and probably about one and one-third times median length. Rostral margin broad and rounded, the shield being semicircular. Length of cornua not known ; pectoral sinuses wide and shallow. Interzonal part short, broad and high. Orbital openings small in middle of length of cephalic shield. Dorsal sensory field, bottle-shaped, two and one-third times as long as broad at the maximum. Lateral sensory fields reaching backwards on to cornua.

Holotype. Imperfect cephalic shield in part counterpart (P.43055).

Locality. Bouldon Ford (about 50 ft. above "*Psammosteus*" Limestone).

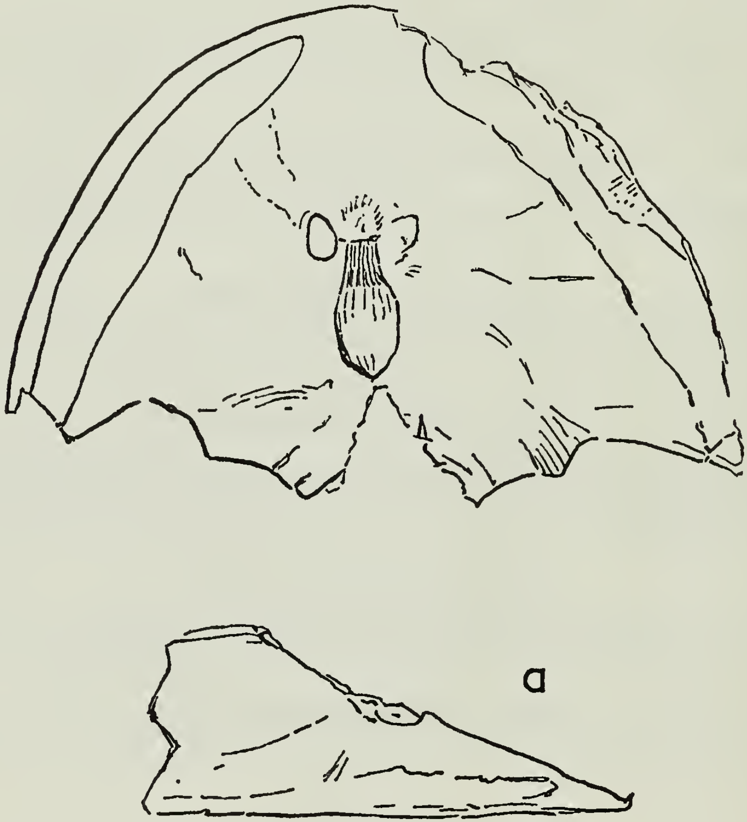


Fig. 6. *Cephalaspis bouldonensis* sp. nov. Imperfect cephalic shield partly restored from counterpart. (a) right side view. See also Pl. 36, fig. 1. The holotype. Bouldon Ford. P.43054–55. × 1·5.

Description. This specimen is in many respects badly preserved, but sufficient is present to show its unique character. The exoskeleton is thin and in poor condition, the greater part of the cornua and the middle of the interzonal part are missing, the right margin defective and the whole somewhat distorted. The shape of the shield is remarkable, for the front margin is completely rounded, and indeed the whole forms a semicircle with the centre just behind the posterior end of the dorsal sensory field. The maximum breadth across the pectoral sinuses (making allowance for the defective right side) is 7 cm. and the length, as preserved, is 4·5 cm.; the height at the back of the shield without the spine (which was certainly present) is 1·3 cm. with a straight facial profile. The specimen is probably not very much crushed.

The orbits lie approximately in the middle of the known length of the shield measured to the hinder lateral margin of the interzonal part. The sinuses are very wide without an angle and shallow.

The dorsal sensory field is narrow in front and then quickly broadens, reaching its maximum breadth near the rounded posterior end.

The normal lateral sensory fields can be clearly made out and they run onto the cornua as far as these are preserved. Nothing can be seen of the ornamentation.

REMARKS. This is one of the most distinctive of the English species, by reason of its completely semicircular shape. *C. langi* Stensiö (1932 : 134), the only other completely rounded form, is not only much smaller, but its eyes are further forward and the interzonal part relatively wider.

INDETERMINABLE CEPHALASPIDS

Other remains of cephalaspids are widely spread although rare and fragmentary. Pieces of the cephalic shields or scales occur in the following localities:

Clee St. Margaret (675 ft. above "*Psammosteus*" Limestone).
Dairy Dingle (800 ft. above "*Psammosteus*" Limestone).
Derrington Rea Bridge (500 ft. above "*Psammosteus*" Limestone).
Earnstrey Brook (70 ft. below "*Psammosteus*" Limestone).
The Hills (Ditton Series, lower group).
Hudwick Dingle 1 (immediately over "*Psammosteus*" Limestone).
Hudwick Dingle 4 (175 ft. above "*Psammosteus*" Limestone).
Kidnall Gutter 1 (15 ft. above "*Psammosteus*" Limestone).
Kidnall Gutter 3 (180 ft. above "*Psammosteus*" Limestone).
Leath 1 (? Ditton Series, lower group).
Ledwyche Brook (60 ft. above "*Psammosteus*" Limestone).
Lye Brook 1 (125 ft. below "*Psammosteus*" Limestone).
Lye Brook 3 (90 ft. below "*Psammosteus*" Limestone).
New Inn 1 (16 ft. below "*Psammosteus*" Limestone).
Oak Dingle (125 ft. above "*Psammosteus*" Limestone).
Park Barn Quarry (80 ft. above "*Psammosteus*" Limestone).
Silvington, Waterfall (600 ft. above "*Psammosteus*" Limestone).
Upton Cresset Quarry (400 ft. above "*Psammosteus*" Limestone).

The range is therefore from 125 ft. below to 800 ft. above the "*Psammosteus*" Limestone.

Class GNATHOSTOMATA

Order ACANTHODII

Acanthodian scales are closely associated with thelodont scales (q.v., p. 258) in their known distribution, and the same remarks apply regarding their probable universality.

Fin-spines of several types (*Onchus*, *Climatius*, etc.) are also fairly widespread but few in number, about 35 distributed over 15 localities. All are either very fragmentary or small. Most are probably referable to acanthodians. At both the New Inn localities partly nodular spines of the type ascribed to " *Climatius* " by Gross (1947, pl. 27) have been found (P.43008–12, P.34284) and from New Inn 2 comes also some of " *Onchus* " type (P.43003–07).

In only four localities have teeth or pieces of jawbone been found. From New Inn 2 (75 ft. above the " *Psammosteus* " Limestone) come several curious " hedgehog " multiple tooth spirals (P.42991–99) similar to those described and figured by Gross (1957 ; 5, pl. 3, figs. 1–7) under the name " *Gomphodus* " from the Upper Ludlow " Beyrichienkalk ", only much larger, up to 6 mm. across without the spines ; and from New Inn 1 (16 ft. below the " *Psammosteus* " Limestone) comes an even larger example, 7 mm. across (P.34287). Still larger tooth spirals, 1 cm. across (P.29709–12) have been collected at Onen, Monmouthshire in association with *Traquairaspis symondsi*.

Genus *ISCHNACANTHUS* Powrie, 1864

Two fragments of acanthodian jawbone have been collected in the area, one from Foxhole Coppice, Monkhopton, and the other from Hudwick Dingle 1. About the former nothing further can usefully be said, but the latter (P.29725 ; Pl. 42, figs. 3, 3*a*) is a fragment of the dentigerous margin of the lower jaw of the type usually referred to " *Ischnacanthus kingi* " and is recorded under that genus by Dineley (1953 : 167).

The name " *Ischnacanthus kingi* " has long been familiar to workers on the Lower Old Red Sandstone of the Welsh Borders, and a practice has grown up of labelling thus all fragments of big acanthodian jaws, and occasionally the term has appeared in print in faunal lists (King, 1934 : 540 ; White, 1945 : 212) ; but no such species has been described, and it is now clear that more than one species is involved.

The first mention of it occurs in 1917 (King & Lewis, 1917 : 97) where it is stated in a footnote that it was " since described in Geol. Mag., dec. 6, vol. IV (1917), p. 74 ". This reference is to a brief note by A. S. Woodward on " *Plectrodus* ", on the second page of which he thanks " Mr. Wickham King for the opportunity of examining the microscopical structure of an unusually large specimen, probably of a new species, which he has recently found in the Downtonian of Baggeridge, S. Staffordshire ". No specific name is mentioned here and " *Ischnacanthus kingi* " remains a *nomen nudum*. However, there are many interesting specimens so labelled in Wickham King's collection and they and others subsequently collected are described below as belonging to two species.

Ischnacanthus kingi sp. nov.

(Pl. 42, fig. 4 ; Text-fig. 7)

Diagnosis. An *Ischnacanthus* of very large size with massive jaws greatly thickened along the upper and lower margins. Teeth acuminate and generally round in section; the smaller teeth relatively large, about one-half or two-thirds the size of the larger teeth.

HOLOTYPE. Imperfect lower margin of palato-quadrate (P.12202) from Baggeridge (zone I.2 of Wickham King).

LOCALITIES AND MATERIAL. The holotype and a second specimen from Baggeridge (zone I.2 of Wickham King) are all that are definitely assigned to this species. The palato-quadrate margin of a small fish from the Ludlow Bone-bed at Brockton, Shropshire (P.33879) and a fragment of a small jaw-bone from Man Brook 2 (P.17395) are rather similar. None is known from the Clee area.

DESCRIPTION AND REMARKS. Clearly this species must be based on the specimen from Baggeridge (P.12202) to which King first applied the name and on which

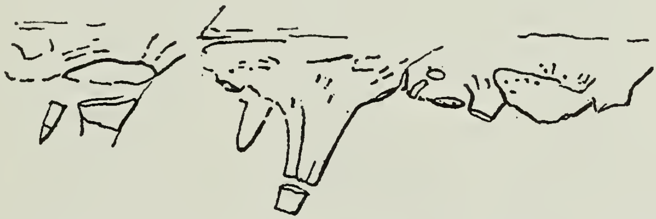


FIG. 7. *Ischnacanthus kingi* sp. nov. Part of dentition of upper jaw. Baggeridge Colliery, South Staffordshire. The holotype. P.12202. × 4·5.

Woodward (1917) wrote his note. It is a very large bone that formed the lower border of the palato-quadrate and measures 10 cm. in length, although lacking a substantial part of both ends. It is 0·8 cm. in depth and shows the lingual side. Unfortunately the tooth-bearing surface is very imperfect and the dentition is represented by the remains of two large teeth, the broken bases of five others and a number of small teeth or their bases (Text-fig. 7).

The most complete tooth is about 0·5 cm. high, acuminate and nearly round in section. The sides show fine vertical ridges. The bases of some of the other large teeth are more oval and between them are the remains of much smaller sharply pointed round teeth, most of which line the vertical flange on the outer side, now broken away. None has a pulp-cavity but in cross-section they show a finely reticular pattern with numerous openings of canaliculi on the surface, exactly like the jaw-bone itself from which they arise gradually. They are apparently outgrowths of the bone-substance, like arthrodire teeth, and not true teeth ankylosed to the jaw.

The second specimen from Baggeridge Colliery is an almost complete right lower jaw of a much smaller fish (Pl. 42, fig. 4). It is just under 7 cm. long and 1·8 cm. at its deepest. Watson's (1937: 79, pl. 9, figs. 3*a*, 3*b*) description of the same bone in the very much smaller *I. gracilis* applies very closely except that this bone shows the outer instead of the inner side of the jaw. The thickened lower margin is deep laterally and so is the upper dentigerous margin. The latter is twisted and almost vertical at the articular end, thus forming a groove for the passage of powerful jaw muscles which were accommodated in the hollow between the two ridges, but in this specimen the thin wall connecting them has been lost. Beyond the point where the two ridges meet there is a long anterior beak-like prolongation, triangular in section and hollow, the " anterior ossification " of Watson, which is externally continuous with the rest of the jaw. The tooth-bearing area is very short, but not quite as short as shown in the figure, since a part behind, as far as the vertical crack, has been broken away. The teeth are of two sizes, as before, and are part of the vertical outer flange. They are narrow and acuminate, but show signs of wear at the tips.

The species is not easily defined in distinction from *I. gracilis*, apart from its great size, since so little is known of it, but the difference between the large and smaller teeth seems to be less here than in the type-species, although the degree of wear may be misleading.

FIG. 8. *Ischnacanthus wickhami* sp. nov. Median spiral tooth-roll. Man Brook 7, Trimpley. P.17397. × 1·5.

Ischnacanthus wickhami sp. nov.

(Pl. 42, figs. 1–3 ; Text-fig. 8)

DIAGNOSIS. An *Ischnacanthus* of great size, with the teeth laterally compressed and sometimes much elongated.

HOLOTYPE. Part of right palato-quadrate margin with teeth (P.24625) from Gardener's Bank, Cleobury Mortimer.

LOCALITIES AND MATERIAL. The only Clee locality is Hudwick Dingle 1. The great mass of the material is from Man Brook 6 and 7 near Trimpley (King's zone I.6). Only single specimens have been obtained from comparable strata elsewhere, the holotype from Gardener's Bank ; P.17409 from near Abberley, Worcestershire, and P.23817–18 from Hay Castle, Brecon. The species would appear to be rather later in range than *I. kingi*.

DESCRIPTION. All the specimens of jaws labelled " *Ischnacanthus kingi* " by Wickham King collected from other localities than Baggeridge Colliery (and presumably subsequently to his collection from that locality) show a very different type of dentition in which the teeth are laterally compressed and sometimes elongated into long shearing teeth. This is best seen in the holotype, a fragment from the right side, from Gardener's Bank, (not collected by King) which has been removed completely from the matrix by acetic acid (Pl. 42, figs. 2, 2*a*). The smaller teeth are very irregular and include the shearing teeth and, as in the preceding species, form part of the upturned lateral margin of the smooth horizontal palato-quadrate shelf which increases in width as it goes forward. As Watson (1937 : 80) states of *I. gracilis*, the series of smaller teeth is " interrupted by the large teeth which are rooted on the surface of the jaw and rise from it with their outer surfaces in complete continuity with the labial flange ". Most of the specimens of this species are jaw fragments of various sizes and were collected by King at Man Brook near Trimpley. They are very imperfect and many show a remarkable degree of wear, the teeth often being reduced to mere stumps (Pl. 42, fig. 1), so it is clear that they were not replaceable and the life of the fish depended on their durability.

Among the remains of the lower jaw is the only specimen from the Clee district, part of the oral margin of the left ramus from a relatively small fish (Pl. 42, figs. 3, 3*a*). All the smaller teeth on the labial flange are laterally compressed and variable in size ; while of the two larger teeth, one is much wider than the other. The oral shelf widens rapidly forwards and bears an irregular series of denticles internally to the main teeth. The bone shows on its outer side the marked oblique groove noted in *I. kingi* above.

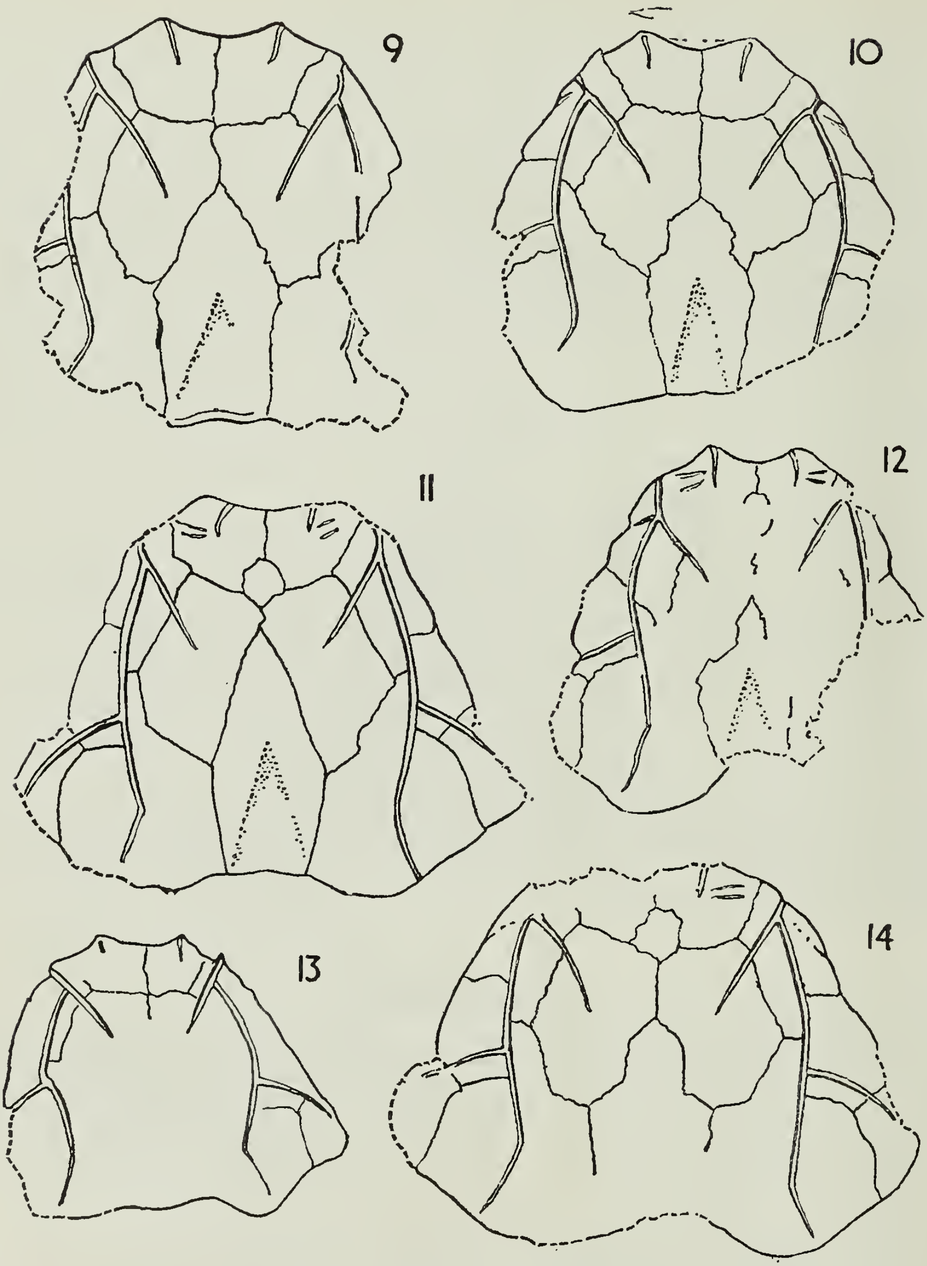
Associated with the jaw-bones at Man Brook is a large symphysial spiral (Text-fig. 8) closely resembling that on the lower jaw in Watson's (1937, text-fig. 11) restoration, and half a dozen smaller ones, as well as a large curved anterior dorsal spine (P.14444) about 9·5 cm. long and parts of another (P.16555). Smooth convex scales are commonly associated with the other parts of the fish.

REMARKS. As already noted these specimens are very like the comparable parts of *I. gracilis* described by Watson (1937). The teeth in their various forms closely resemble those on the minute jaws from the Upper Ludlow " Beyrichienkalk " figured by Gross (1957 : 13, pl. 5, figs. 2–9) as " *Nostolepis* ", a genus based on scales supposedly of coelolepid origin (Pander, 1856 : 68, pl. 6, fig. 7), but the associated symphysial spirals are very different. The rounded form of some of the teeth described by Gross (1947 : 148, pl. 9, fig. 3), so apparent in those from Man Brook, seems to be due to wear.

Order ARTHRODIRA

Rare specimens that have been referred to arthrodires have been identified from six or seven localities. They are all small fragments of plates or spines that cannot be assigned to a particular genus, although most are clearly arctolepid, with three exceptions which are all referable to *Kujdanowiaspis anglica*. The localities for the indeterminable remains are :

Batch Brook (800 ft. above " *Psammosteus* " Limestone).
Clee St. Margaret (675 ft. above " *Psammosteus* " Limestone).
? Cold Weston Quarry (850 ft. above " *Psammosteus* " Limestone).
Criddon Bridge (5 ft. above " *Psammosteus* " Limestone).
Poston Old Quarry (800 ft. above " *Psammosteus* " Limestone).



Figs. 9–14. *Kujdanowiaspis anglica* (Traquair). Outlines of six skull-roofs to show range in variation of component plates. All nat. size. (9) P.27550, Silvington Waterfall. (10) No. 42147, Cradley, Herefordshire. (11) Geol. Surv. No. 4740, " Hereford " (probably Heightington). (12) No. 38032, Heightington, Worcestershire. (13) P.29417, Cradley (cast of holotype in Royal Scottish Museum, No. 1926. 57·2.) (14) Geol. Surv. No. 4417, Heightington, Worcestershire.

Genus *KUJDANOWIASPIS* Stensiö, 1942

Kujdanowiaspis anglica (Traquair)

(Pl. 45, fig. 7; Text-figs. 9–15)

LOCALITIES AND MATERIAL. Three specimens only may be certainly attributed to this species: the external impression of a head-shield from Silvington, Waterfall (600 ft. above "*Psammosteus*" Limestone); the internal impression of the left anterior quarter of the ventral armour from Hoptongate (700 ft. above "*Psammosteus*" Limestone) and an anterior ventro-lateral plate from Rea Brook, New House Farm (650 ft. above "*Psammosteus*" Limestone).

DESCRIPTION. The impression of the skull (P.27550; Text-fig. 9) is finely preserved and on it may be traced the outlines of the component bones and the course of the sensory canals. It may be compared with the sketches of the other known skull-roofs of this species (Text-figs. 10–14) which show the great variation in the shape of the individual plates (see also Text-figs. 42, 43).

The second specimen, from Hoptongate (P.27097; Text-fig. 15) shows, mostly as internal impressions, the left anterior ventro-lateral plate, the anterior median ventral plate and part of the inter-lateral plate with coracoid process of a young fish. The whole is only 2·8 cm. long, and the tubercles of the ornamentation are correspondingly fine. It is very much as in Stensiö's (1944: 60, text-fig. 17B) restoration of a Podolian form.

The last, from Rea Brook, New House Farm, Neenton, is a very well preserved triangular piece consisting of part of the right anterior ventro-lateral plate with the spinal plate and a very small fragment of the inter-lateral plate (P.29821; Pl. 45, fig. 7). It measures 3·7 cm. across and 2·8 cm. from the anterior margin to the

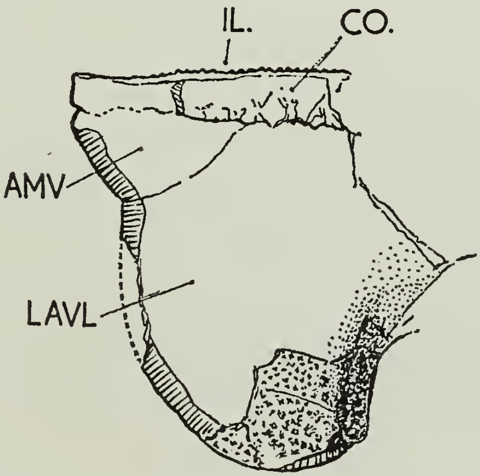


FIG. 15. *Kujdanowiaspis anglica* (Traquair). Left anterior quarter of the ventral armour of a small fish, largely an internal cast. AMV, anterior median ventral plate. Co, coracoid. IL, interlateral plate. LAVL, left anterior ventro-lateral plate. Hoptongate. P.27097. × 2.

pectoral sinus. Apart from the pectoral sinus and the contact with the spinal plate, the margins are missing, but the spinal plate is complete except for the free portion. In no important feature does it differ from specimens from elsewhere, but the ornamentation, developed by acid, is very clear. On the AVL plate the rounded tubercles tend to run in lines very roughly parallel with the margins. Most are somewhat rubbed but it can be seen that they were rather small and low with crinkled bases. The tubercles along the free lateral margin of the spinal plate are larger and taller, and their size and arrangement in numerous parallel longitudinal rows mark them off from the ornamentation on the undersurface.

Remarks. All these specimens may be considered typical of this as yet indifferently described species, which is widely spread, although generally rare, in corresponding strata in Herefordshire.

Arthrodires range throughout the whole of the lower group of the Ditton Series, extending into the middle of the upper group, i.e. from 5 ft. to 1,100 ft. above the " *Psammosteus* " Limestone ; and *K. anglica* is known from 600 ft. to 1,100 ft. above the " *Psammosteus* " Limestone.

II. FAUNA OF THE UPPER GROUP OF THE DITTON SERIES

The most striking feature of the fauna of these upper beds is the high incidence of new forms, ten out of twelve named species, four of them here referred to new genera. On the other hand *Kujdanowiaspis anglica* is a rather unexpected survival from the lower beds, where it is widely distributed along the Welsh Marches, although rather rare ; and *Pteraspis* (*Cymripteraspis*) *leachi* provides a useful means of correlation with continental strata of Lower Siegenian age (Schmidt, 1960 : 140).

Class AGNATHA

Order HETEROSTRACI

Genus ***PROTASPIS*** Bryant, 1933

Subgenus ***EUROPROTASPIS*** nov.

Denison (1953 : 318) has re-defined the genus *Protaspis* in the light of new information, but his diagnosis is based largely on the American species. He notes, however, that in *P. arnelli*, the only well-known form from Europe, that the position of the branchial opening and the form of the cornual plate are different, but nevertheless states that these differences " are hardly adequate to characterize a new genus " in spite of the possibility that the Podolian species " may have acquired its *Protaspis*-like characteristics independently " (1953 : 326). These features seem to be worth at least subgeneric distinction, especially as there are other differences in *P. crenulata*, particularly in the pre-oral field and in the squamation. I therefore propose a new subgenus, *Europrotaspis*, to include the new species from Shropshire and *P. arnelli* from Podolia.

The difference between the pre-oral fields is indeed most marked, for in the English species it is large and flat (Text-fig. 17), whereas in the specimen referred to *P. bucheri* (Denison, 1953, text-fig. 78) it is virtually non-existent.

There are two most puzzling features about the scales of *P. crenulata* (all isolated ; there are no scales recorded of *P. arnelli*) which seem to separate it widely from the American species. The more marked is the very large size of the associated ridge-

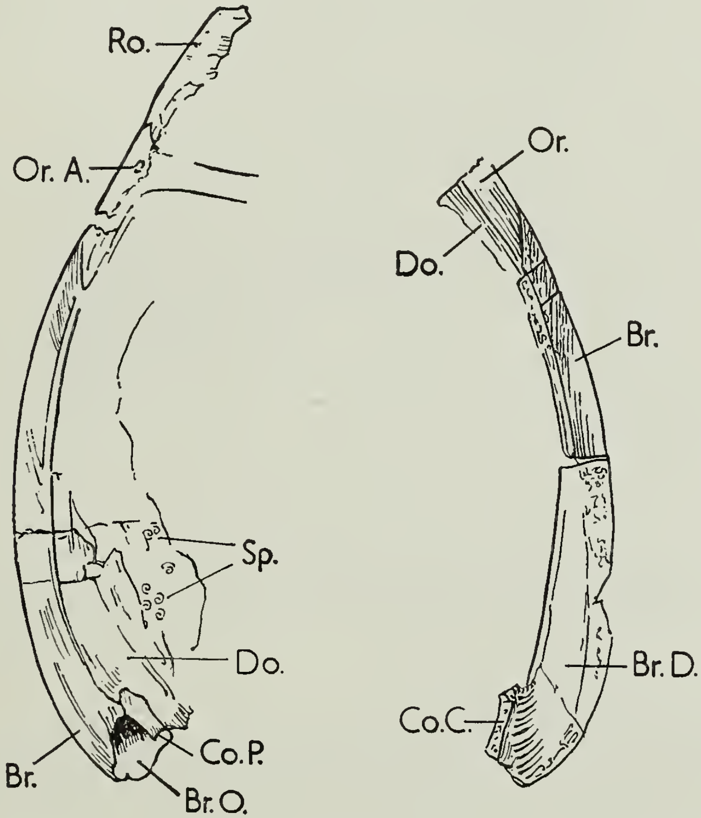


Fig. 16. *Protaspis* (*Europrotaspis*) *crenulata* sp. nov. Imperfect dorsal shield. The holotype. Besom Farm Quarry. P.28801. Slightly enlarged. *Br.*, branchial plate ; *Br.D*, branchial duct ; *Br.O*, branchial opening ; *Co.C*, cornual contact surface on branchial plate ; *Co.P*, cornual plate ; *Do*, dorsal disk ; *Or*, orbital plate ; *Or.A*, orbital aperture ; *Ro*, rostrum ; *Sp*, shells of *Spirorbis* attached to undersurface of dorsal disk.

scales, which, relative to the largest plates known, are much greater than those figured in the tailed specimens of the American species, although these are large compared with those recorded in other pteraspids (Bryant, 1934, pls. 22, 23, 24, fig. 1 ; Denison, 1953, text-fig. 74). Even more surprising is the fact that a number of them are strongly asymmetrical, with a marked keel and almost flat underside, which clearly suggest a lateral series—an entirely novel feature in pteraspids unless Zych's (1931, figs. 41, 49) restorations of Podolian species of *Pteraspis* are to be taken seriously. The existence of a lateral series of ridge-scales is supported by the shape of the branchial plates which corresponds to that of the scales, for there is an acute longitudinal keel separating the flat undersurface from the convex upper surface.

Whether these characters occur in all the European forms is not yet known, but the shape of the branchial plates in the Podolian *P. arnelli* as restored by Brotzen (1936, text-fig. 3) suggests that they do occur in that species at least.

There are two other points in Denison's (1953) diagnosis that may be called into question: the first is the length of the rostrum, which is stated to be " very short to moderately long ". Presumably the " moderately long " refers to *P. priscillae*, but the reference of this species to *Protaspis* seems very doubtful, for none of the critical hinder part of the shield is known. More important is the supposed shape of the tail, which Denison describes as being short and " nearly symmetrical ". The irregularity of the tail that he figures (Denison, 1953, text-fig. 74), not only in shape but also in the arrangement of the marginal scales, proclaims it to have been malformed (compare that of " *Malania* ", the second specimen of the living coelacanth—see White, 1953 : 114, text-fig. 3). The diminution in size of the scales on the tail of *Pteraspis* is perfectly regular, like the shape itself, and there are small fulcral scales on both margins of the lobe. Either the tail of this specimen was injured when young and has grown irregularly, or it has been bitten off and partly regenerated. Moreover, there is reason to believe that the specimen is figured upside down, for the scaling at the end of the rows, as illustrated, runs upwards and backwards instead of the normal downwards and backwards, and in *Pteraspis* it is the dorsal series of ridge-scales that tend to be long and narrow and the ventral series that are short and deep (the depth of the " upper " series as figured by Denison is clearly seen in his figure 74A, although not in his restoration). When a laterally compressed tail is twisted at right angles to a rigid body, it is not always easy to see which way it has gone.

Diagnosis. *Europrotaspis* is defined as a subgenus of *Protaspis* in which the cornual plate is reduced to a short narrow element lying between the dorsal disk and the end of the elongated branchial plate ; the branchial opening is large, terminal in position and partly directed upwards ; the snout short with a well-developed wide pre-oral field having a slight posterior median ridge ; ridge-scales probably extremely large relative to the body-size and arranged, in addition to the usual symmetrical dorsal and ventral series, in very asymmetrical lateral series following the branchial plates, which have an acute longitudinal keel and a flat undersurface.

Species. *P. crenulata* sp. nov., the subgenotype ; *P. arnelli* Brotzen and possibly *P. wiheriensis* Brotzen and *P. rotunda* Gross.

Protaspis (Europrotaspis) crenulata sp. nov.

(Pls. 43, 44 ; Text-figs. 16–33)

Diagnosis. An *Europrotaspis* with rostrum rounded and median length of upper surface contained about four and a half times in that of dorsal shield; dorsal disk with maximum breadth somewhat less than median length and narrowing only moderately towards anterior end. Dentine ridges of superficial "ornamentation" coarse, average 5–6 per mm., when unworn A-shaped with relatively coarse lateral denticulations continued on to the ridges, giving a crenulate appearance.

HOLOTYPE. An imperfect dorsal shield (P.28801).

MATERIAL. In addition to the holotype, about 70 specimens, including a dorsal disk; one almost complete and two fragmentary ventral disks; three incomplete branchial plates; 34 isolated scales and about 30 other fragments.

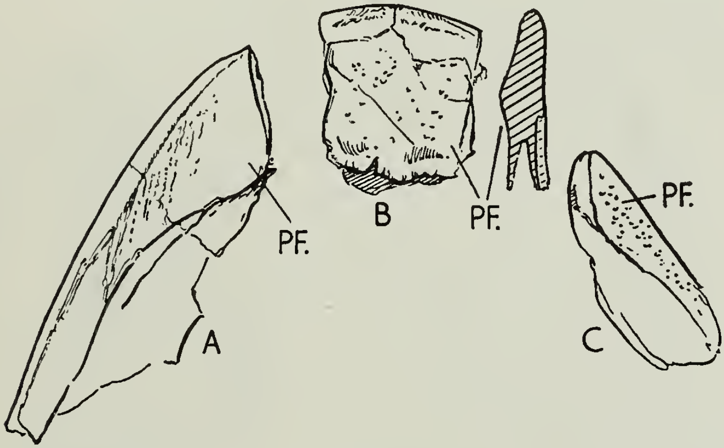


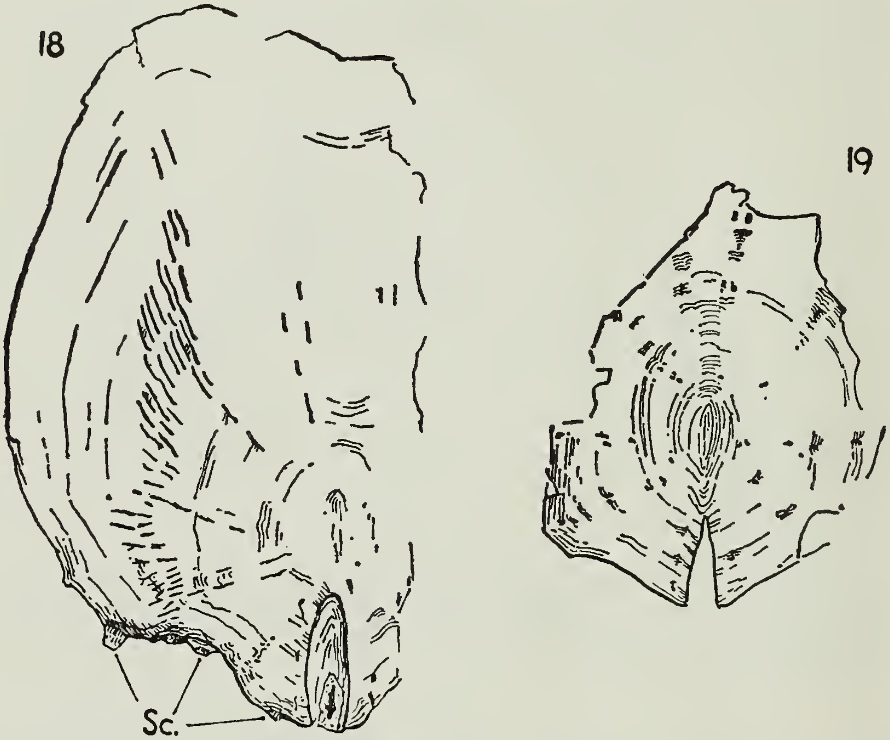
FIG. 17. *Protaspis* (*Europrotaspis*) *crenulata* sp. nov. A, B, C, three fragments of different rostra, ventral view, with median longitudinal section of centre fragment, showing the pre-oral field (*PF*). Besom Farm Quarry. P.33832, P.28802, P.28825 respectively. × 2·25.

LOCALITIES. The most important is the old quarry ¼ mile SE. of Besom Farm, Wheathill, Shropshire; another is Upper Overton Quarry, nearly 5 miles to the north-east. Exposures at Prescott Reaside and Farlow Brook Bridge have also yielded some good specimens. Scales and fragments have been found at three or four other places in the neighbourhood.

DESCRIPTION. The holotype is an eroded and primarily imperfect dorsal shield (Text-fig. 16). The right side of the rostrum and most of the right orbital plate were lost before fossilization, and subsequently almost the whole of the dorsal disk and the dorsal side of the right branchial have been removed by weathering, the specimen being on a loose surface block. The left branchial plate with the minute cornual is very well preserved, the posterior half being uncrushed (as was presumably the whole specimen) and preserved in the round.

An interesting feature of this specimen is the occurrence of a number of small spiral shells attached to the inner surface of the dorsal disk (Pl. 43, fig. 3; Text-fig. 16, *Sp*). These are apparently the remains of *Spirorbis* sp. and indicate that the carapace had lain exposed on the bottom for some considerable time after the decay of the soft parts and before being covered over. This perhaps accounts for the fractured state of the rostrum.

The length of the fossil from the broken tip of the rostrum to the end of the left branchial plate is 9·2 cm. and the maximum breadth, at about 3·5 cm. in front of the hinder end of the branchial, is 7 cm.



Protaspis (*Europrotaspis*) *crenulata* sp. nov.

FIG. 18. Imperfect, flattened dorsal disk of adult, possibly aged animal, showing base of dorsal spine and small scales (*Sc.*) attached to left hinder margin. Upper Overton Quarry. P.29415. × 1·5.

FIG. 19. Imperfect part-grown dorsal disk in impression with indications of sensory canals. Besom Farm Quarry. P.26313. × 1·5.

Probably little has been lost of the rostrum in length, for fragmentary specimens of this plate indicate that it was very much rounded in front (Text-fig. 17). If so, its length was contained about four and a half times in the total length of the shield, omitting the dorsal spine.

The orbital plates were small with very small orbits, but the mesial processes were broad and certainly met the pineal plate, which is unknown, completely separating the rostrum from the dorsal disk.

The anterior margin of the disk is shallowly but widely indented with rounded corners, and the posterior margins are sigmoidally excavated (Pl. 43, fig. 1; Text-fig. 18). In this fully grown specimen a number of very small scales are fused to the hinder margin, the largest being immediately behind the cornual plate and fitting on to a short emargination of the disk. These small scales are probably no more than a manifestation of old age, which is often shown in compression, fusion

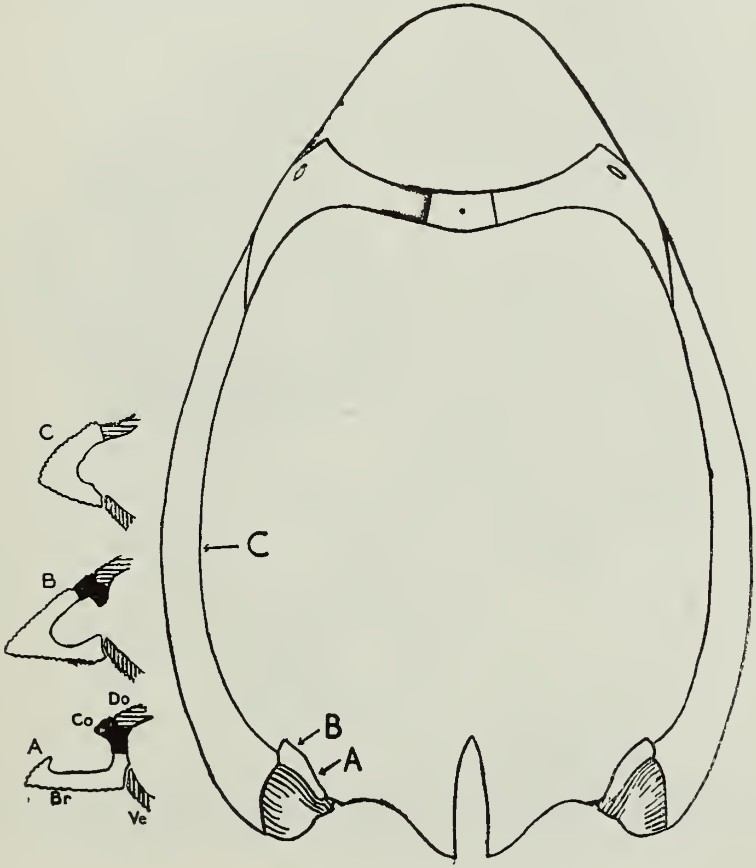


FIG. 20. *Protaspis* (*Europrotaspis*) *crenulata* sp. nov. Restoration of dorsal shield in outline, with enlarged cross-sections through branchial plate, etc., at A, B, and C. × 1 approx. *Br*, branchial plate; *Co*, cornual plate; *Do*, dorsal disk; *Ve*, ventral disk.

and other irregularities commonly seen along the margins of the disks of pteraspids. They have nothing to do with the definite structures which Denison calls " posterior scale-like process of cornual plate ".

The sides of the dorsal disk are moderately convex, particularly in the hinder quarter as the cornual plate is approached, for which there is an emargination varying in definition with age, being most marked in the oldest specimens (Text-fig. 16), scarcely perceptible in the half-grown (Text-fig. 19), and altogether absent in the young which have the usual rounded outlines (P.28881).

The socket for the dorsal spine is relatively short in the adult, occupying about one-fifth of the median length of the dorsal disk. Of the spine itself only the basal portion is known (Pl. 43, fig. 1; Text-fig. 18; P.29076), but to judge from these fragments it was clearly stout and low, coming off the disk at about 30°, and probably short.

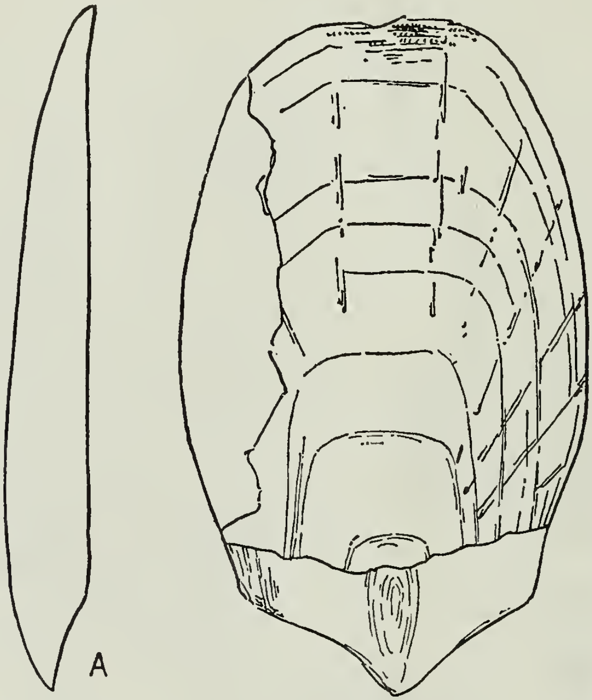
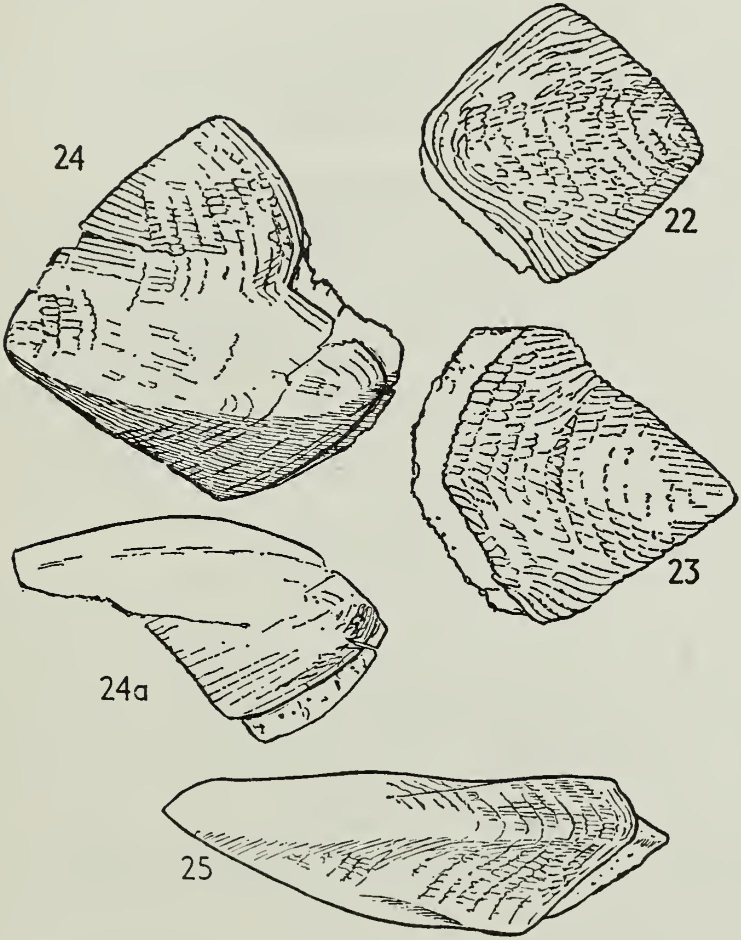


Fig. 21. *Protaspis* (*Europrotaspis*) *crenulata* sp. nov. Ventral disk, mostly in impression, with posterior marginal area added from second specimen. A, side view in outline. Besom Farm Quarry. P.26311, P.28803. Slightly enlarged.

The degree of convexity of the dorsal disk is not known, for this plate is largely abraded in the holotype and the other specimens are flattened.

The branchials are massive plates with a convex upper surface separated by an acute lateral longitudinal keel from the undersurface which to the rear becomes flattened and almost horizontal (Pl. 43, fig. 2; Text-figs. 20A–C). The upper margin is, as usual, firmly attached to the dorsal disk over most of its length, to the orbital plate in front, and to the cornual plate behind, but contact with the last-named is only a millimetre or two long. The contact of the lower flange, which is wider than the upper, met the ventral disk along a slightly concave free edge.

Except at the posterior end where dorsal and ventral inner margins were very briefly connected by the diminutive cornual, the branchial plate was open to the body and formed the common branchial duct, deep behind and shallowing forwards. The upper surface shows remains of two of the ridges dividing branchial pouches.



Protaspis (*Europrotaspis*) *crenulata* sp. nov.

FIGS. 22, 23. Flank scales. P.29068, P.27516. × 7·5.

FIG. 24. Supposed anterior ventro-lateral ridge-scale in side view and (*a*) from below. P.27515. × 7·5.

FIG. 25. Supposed ventro-lateral ridge-scale. P.28884. × 2·8.

All from Besom Farm Quarry.

The external branchial aperture opens obliquely upwards, being floored by the longer, lower flange of the branchial plate and walled medially by the cornual, precisely as in the Podolian species, *P. arnelli* Brotzen (1936, text-fig. 3).

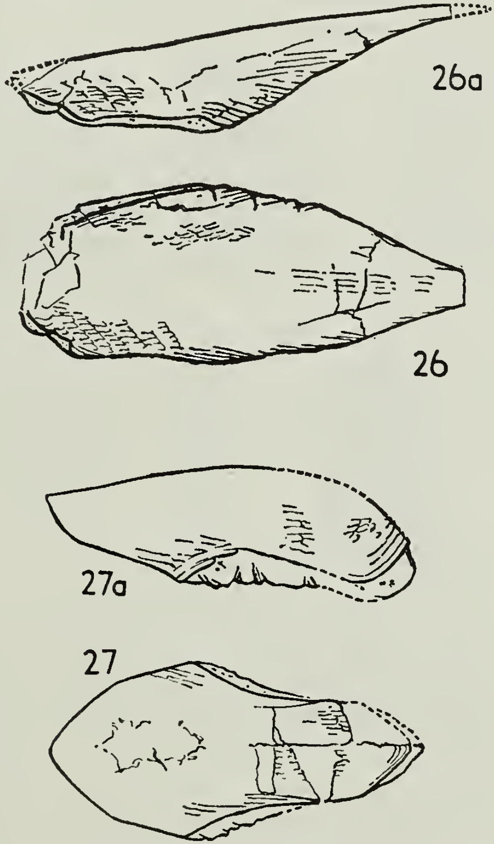
The ventral disk (Text-fig. 21) is of the type usual in most pteraspids, ovate in outline with the posterior end bevelled on each side to form a blunt median projection. The plate is moderately convex along both axes, with the anterior end flatter than the hinder, like the dorsal disk. As in all these animals the edges were free, smooth and slightly convex, and the plate was attached to the branchials only by soft tissues, which explains why the ventral disk is always found isolated except in rare instances when the whole creature is preserved. The reason for this looseness of attachment was probably to provide flexibility to allow rhythmic movement as an aid to breathing, comparable to that provided by the very different branchial mosaic in cephalaspids.

The only other skeletal parts preserved are isolated scales. The flank-scales (Pl. 43, fig. 5 ; Text-figs. 22, 23), of which there are about 25 examples, are of the usual type in pteraspids, thick, more or less diamond-shaped with a narrow overlapped margin lacking the external layer along one or both of the anterior margins of the quadrate ornamented surface (cf. White, 1935, pl. 27, text-figs. 61, 62 ; 1938, text-figs. 6–9 ; 1950*b*, text-figs. 10–13). They vary somewhat with their position on the body (e.g. P.26316, P.27517, P.28826–27, P.28864–65, P.28905, P.29086). Compared with the associated plates of the carapace, of which none is substantially larger than those of the holotype, these scales are very large indeed : relatively they are twice as large as those in the complete specimens of *Pteraspis* (*P.*) *rostrata toombsi*, and in actual size they come within the range of those of the very much larger *P.* (*Cymripteraspis*) *leachi*, which occurs with them. Fortunately the pattern of the ornamentation in the two species is distinctive.

The curious double flank-scales noted in species of *Pteraspis* (White, 1935 : 413 ; 1950, text-figs. 13, 14) are also present in *Protaspis* (*Europrotaspis*) *crenulata*, but here some at least seem to have formed part of a definite series. These very large scales, of which the one shown in Text-fig. 24 is 1·1 cm. high over the curve, have a lower flange bent almost at right angles to the lateral face, and it seems evident that they formed the anterior part of a ventro-lateral series of ridge-scales covering the angle between the sides and the more or less flat undersurface, following behind the even more angular branchial plates (Text-fig. 20A–C). This row of asymmetrical scales formed a graded series (Text-fig. 24 ; Pl. 44, fig. 3 ; P.28874) to scales of very elongated form but still notably lacking in symmetry (Text-fig. 25).

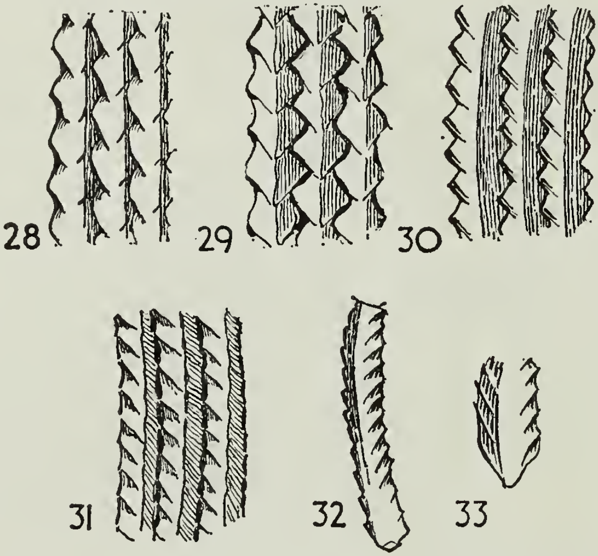
The median ridge-scales (Text-figs. 26, 27 ; P.26315, P.28885) attain the same astonishing size, up to 2·5 cm. in length, and apart from their obvious symmetry, they are distinguished by the fact that the overlapped margin continues along the whole of the sides of the attached surface, which in the most elongated specimens is much less than half the total length, for the hinder part is raised into a free spine with the underside flat and ornamented like the upper surface. By analogy with *Pteraspis* (White, 1935 : 417–418) the elongated scales with the free ends may be assigned to the dorsal series, the broader to the ventral. All the specimens show signs of wear along the central area. A juvenile dorsal scale, only 1 cm. long (Pl. 44, fig. 2), has an attached surface of only 0·4 cm. and this is deeply hollowed out with a median foramen. There were no overlapped margins.

There is no doubt that these scales belong to this species, the ornamentation makes that clear, but as in the similar case of *Pteraspis leathensis* White (1950 : 79), there must be some uncertainty as to the relative sizes of the scales and plates owing to the possibility of water-sorting. As in the *Pteraspis*, however, the relative maximum sizes of plates and scales do not vary substantially from one locality to another.



FIGS. 26, 27. *Protaspis* (*Europrotaspis*) *crenulata* sp. nov. Dorsal and ventral ridge-scales respectively, in direct and (*a*) restored side-view. Besom Farm Quarry. P.28828, P.28886. × 3.

The ornamentation on the plates of the carapace and on the scales is of the usual ridge-and-furrow type found in all the pteraspids, but is coarser than in most species, the ridges in general running as few as 5–6 per mm. (except, as usual, near the centre of plates where they are often fewer, and near margins, particularly the postero-lateral areas of the disks, where they are more numerous). The ornamentation follows the normal pattern on all the plates but some of the disks show extreme irregularity in the centre. In the ventral disk figured in Pl. 43, fig. 4 the greater part of the plate, instead of being covered by the usual series of ridges running parallel with the front and sides, is divided into two by a longitudinal series, which meets the normally disposed series at the margin almost at a right angle. It was an arrangement such as this constantly occurring in *Pteraspis dixoni* that led Stensiö (1958 : 292) in the belief that such a pattern signified a different mode of development, to place this otherwise obvious species of *Pteraspis*, not only in a new genus, *Penygaspis*, but in a different Order, the Traquairaspida. As an irregularity it occurs occasionally in other species of pteraspids.



Protaspis (*Europrotaspis*) *crenulata* sp. nov.

FIGS. 28–33. Variations in the ornamentation. All × 40 approx. (28) From front end of dorsal disk. Besom Farm Quarry. P.28808. (29) From posterior end of ventral disk. Besom Farm Quarry. P.28809. (30) From undetermined fragment. Farlow Brook Bridge. P.29003. (31) From top end of branchial plate, medial side. Besom Farm Quarry. P.29076. (37), (38) From anterior and ventro-lateral areas of a scale. Besom Farm Quarry. P.29077.

The disks of the larger, and presumably old, specimens of *Pr.* (*E.*) *crenulata* show another deviation from the normal pattern near the anterior margin, where, instead of ridges, there are parallel bands of short segments at right angles (Pl. 44, fig. 7).

As is often the case, the pattern on the scales shows some specific individuality (Text-figs. 22–27). On the flank-scales the ridges run lengthwise across as usual and are divided over most of the exposed surface into short lengths by arched grooves parallel with the anterior margin at intervals that increase slightly to the rear. What is unusual is that the grooves do not reach the lower angle nor sometimes the top. The segments of ridges between each pair of grooves do not lie in line with those next to them but roughly alternate with them.

In some scales a few ridges run in front parallel with the margin, while in others this area is covered irregularly with short, broad segments.

A similar type of ornamentation is borne by the ridge-scales, but the increase in the spacing of the grooves towards the posterior point is more marked.

One feature clearly distinguishing this ornamentation is that the ridges themselves are ornamented, for in all British species of *Pteraspis* in which the ornament has been described in detail the very fine lateral denticulations which characterize the ridges in this genus lie in the grooves between them, and the ridges themselves, whatever their shape in cross-section, are absolutely smooth.

In *Pr.* (*E.*) *crenulata* the denticulations are continued on to each side of the ridges, which when fresh are sharply A-shaped (Pl. 44, fig. 4; Text-figs. 28–33). When slightly worn the ridges have a beaded appearance, allowing small fragments to be identified with ease (Pl. 44, fig. 5). Further wear, which is usual over much of the larger plates, may obliterate this feature and the ridges become flat and plain resembling those of other pteraspids in this condition.

It is probable that this ornamentation, or a variant of it, is to be found in other, if not all species of the subgenus, and possibly of the genus. A specimen referred to *Pr.* (*E.*) *arnelli*, kindly lent to me by Professor Stensiö, clearly shows a beaded ornament (Pl. 44, fig. 6).

The sensory canal system so far as it is known is exactly as in *Pteraspis* (Text-figs. 18, 19, 21). In the adult the pores opening onto the external surface are often very obscure except those of the outer longitudinal lines, where they are, on the contrary, extremely long and conspicuous. The median anterior loop on the ventral disk reaches far backwards and the medial branches of the marginal lines are also long.

Remarks. The first fragments of this new pteraspid were found by Professor L. J. Wills some years ago. It was then regarded as an unusual form of *Pteraspis* itself, useful as providing an easily identified marker of post-*crouchi* Dittonian strata (see White, 1950 : 53, text-fig. 1); but the unique but imperfect dorsal shield found by Dr. Ball (described above as the holotype) shows that it has the long branchial plates and reduced cornuals typical of the genus *Protaspis*, first described from Wyoming (Bryant, 1933 : 294) and subsequently recorded from West Podolia, Belgium and possibly also from the Rhineland (Brotzen, 1936 : 20). More recently Denison (1953 : 318–350, text-figs. 71–83) has given an excellent account of the Wyoming species and added a number of new forms from Utah.

This species is easily separated by its general form from the other European species that have been referred to this genus. It is far less exaggerated in its shape than the continental species, which are very broad in the disks, while the rostrum is more rounded than in *Pr.* (*E.*) *arnelli*. An examination of the type-material of this latter species suggests that it does not present the curious form shown in Brotzen's (1936, text-fig. 6) restoration, but is more like that in the English species, nor is the socket of the dorsal spine, although short, enclosed by the dorsal disk.

Genus *PTERASPIS* Kner, 1847

Subgenus *CYMRIPTERASPIS* White, 1960

In recent years considerable attention has been paid to the oral region of the species of *Pteraspis*, and it is clear that the form of the pre-oral field is of much systematic importance. Hitherto *P. dunensis* and *P. leachi* have been associated in the same subgenus *Rhinopteraspis*, but the discovery of the large triangular pre-oral field in *P. dunensis* (Tarlo, 1958 : 8), comparable with that in *P.* (*Belgicaspis*) *crouchi* (White, 1956 : 8, text-fig. 1) separates that species widely from *P. leachi*, in which the pre-oral field is very small (White, 1956 : 8, text-figs. 1–4). As in *P.* (*B.*) *crouchi*, the pre-oral field in *P.* (*R.*) *dunensis* is a separate plate developed independently of the rostrum and very rarely preserved, whereas in *P. leachi*, as shown by recent re-examination of the original specimens, although a separate plate with its own concentric ornamentation, it is firmly attached to the rostrum in all the specimens known.

A further difference between *P. dunensis* and *P. leachi* lies in the cornual plate : in the former it has never been seen and must have been very small if it existed at all ; whereas in *P. leachi* it is long and fairly deep, but with scarcely any horizontal flange. *P. leachi* has also more horizontally protuberant orbital plates with a wide groove sharply demarcated running along the lower margin.

From the species referred to *Althaspis* Zych (= *Pseudopteraspis* Stensiö), *P. leachi* differs quite clearly by the possession of a small discrete pre-oral plate, which is concentrically ornamented but, apart from an external groove marking its outline, is, at least in adult specimens (the only specimens known), fused with the pre-oral margin (cf. White 1956, text-fig. 4 ; Stensiö 1958, text-figs. 136, 144, 157, 191*A* ; White 1960, pl. 2, fig. 1).

P. leachi has therefore been placed in a separate subgenus, *Cymripteraspis* (White, 1960 : 8).

Pteraspis (Cymripteraspis) leachi White

(Pl. 45, figs. 1, 2 ; Text-figs. 34, 35)

1938 *Pteraspis* (*Rhinopteraspis*) *dunensis* var. *leachi* White, p. 87, text-figs. 1–10.
1956 *Pteraspis* (*Rhinopteraspis*) *leachi* White, p. 6, text-fig. 3.
1959 *Pteraspis* (*Rhinopteraspis*) *leachi* White : W. Schmidt, p. 54, pl. 1, figs. 4–7 ; pl. 2, figs. 1–7 ; pls. 3, 4 ; text-figs. 4 (2), 10–13.
1960 *Pteraspis* (*Cymripteraspis*) *leachi* White, p. 8.

Localities and material. Fragments of this species are more widely spread in the Clee district than are remains of *Protaspis crenulata*, for they occur at the same eight localities and half a dozen more ; but the great majority are very trivial, and except at Prescott Reaside and Besom Farm Quarry, which account for more than half of the total of about 60, they are rare.

Description. The largest fragment, measuring only 4 × 3·5 cm., is from the right anterior quadrant of a dorsal disk from Lower Ingardine Ford (P.27548–49). The best specimens from Besom Farm Quarry are three pieces of branchial plate, each with part of the dorsal disk attached. The largest (P.28811) is about 3·7 cm. long and from the left side. It shows well the laterally flattened form of this plate characteristic of the species. The other two fragments are both from the anterior end of right branchials (P.33836–37). All show close resemblance to the corresponding parts in the original specimens from Swanlake Bay.

The only other specimens worthy of individual note are an imperfect right orbital plate (P.29198) and a good flank-scale (P.29261), both from Prescott Reaside. The orbital plate (Text-fig. 34) lacks the medial process, the anterior projection and the most posterior third of its length, measuring as preserved 2·0 cm. Nevertheless, it resembles closely the orbitals in the original specimens from Swanlake Bay (Text-fig. 35), being laterally protuberant and overhanging with a wide, sharply defined, suborbital groove running parallel with the inferior margin, above the very defective overlapped border. It clearly differs from the plate in *P.* (*Rhinopteraspis*) *dunensis* in which the groove is absent (Text-fig. 36).

34

35

36

Pteraspis (*Cymripteraspis*) *leachi* White

FIG. 34. Imperfect right orbital plate. Prescott Reaside. P.29198. × 3 approx.

FIG. 35. Restoration of right orbital. Based on P.18048. Swanlake Bay. × 2 approx.

Pteraspis (*Rhinopteraspis*) *dunensis* (Roemer)

FIG. 36. Right orbital. Emsian: Schleiden, Eifel. P.31629. × 2 approx.

The typically diamond-shaped flank-scale is small, measuring 0·6 cm. long and 0·7 cm. high without the anterior overlapped margin, which is imperfect (Pl. 45, fig. 2).

All the plates have the typical ornamentation of very fine, flat ridges so closely appressed that the minute lateral denticulations are rarely to be seen except on the scales. On the whole the ridges are slightly finer than on the Swanlake type-specimens, numbering 8–10 per mm. (except on marginal or central areas, where they are in all species finer and coarser respectively) as against $6\frac{1}{2}$–9. As in the Swanlake scales the chevron-shaped grooves run parallel with the anterior margin and divide up the ridges on the exposed surface. These are evenly spaced at about 2·5 mm. intervals. Near the front border the ornamentation tends to be irregular.

REMARKS. That these specimens are referable to *P.* (*C.*) *leachi* is evident. The slightly finer ornamentation may be a local variation, or it may have time significance. Specimens of this species discovered by Professor Ubaghs near Pepinster in Belgium (White, 1960 : 8) show the opposite tendency and are somewhat coarser in the ornamentation than the Swanlake specimens, which may, therefore, be intermediate in age. But even if there is such significance in this variation, it is not clear which way the series runs, for there is no field evidence in these widely separated localities that I know of, nor are there associated faunas at Swanlake or at the locality near Pepinster to indicate differences in age. However, on the analogy of the greatly increased coarseness in the ornamentation of the later species, *P.* (*Rhinopteraspis*) *dunensis*, it is perhaps more likely that the tendency is from fine to coarse, and that the Clee beds are somewhat older than those at Swanlake and those near Pepinster the youngest.

Order OSTEOSTRACI

Genus ***BENNEVIASPIS*** Stensiö, 1927

Benneviaspis salopiensis sp. nov.

(Text-fig. 37)

Diagnosis. A *Benneviaspis* of moderate size with maximum breadth of cephalic shield, without cornua, about one and a half times median length. Rostral margin rounded, lateral margins convex. Cornua unknown, but with narrow bases and almost certainly small. Pectoral sinuses of moderate width and depth. Interzonal part short with short and wide median projection, and negligible postero-lateral angles. Dorsal sensory field very large, almost reaching margin of posterior projection, somewhat wider than long, broadly lonzenge-shaped with well-defined lateral angles and slightly convex antero-lateral margins. Lateral sensory fields narrow with small postero-median angle.

Holotype. Imperfect cephalic shield in counterpart (P.29720–21). The only specimen.

Locality. Besom Farm Quarry.

Description. This specimen is in many respects badly preserved, but sufficient is present to show its unique character. The exoskeleton, as usual very thin, is in poor condition, the cornua are missing, the right margin defective and the whole somewhat distorted. As preserved, the shield is 5·5 cm. in breadth and 4·0 cm. in median length. The left eye is distorted but the right measures 4×3 mm.: they lie a little behind the mid-point of the shield, not far in front of the level of the pectoral sinuses. The sinuses are moderately deep and not very wide owing to the relative breadth and shortness of the interzonal part. The missing cornua have narrow bases and were probably short.

The hinder margin of the shield has a very wide median projection on each side of which the border is shallowly concave and meets the lateral margins in a right angle, so that the postero-lateral projections or angles are virtually absent.

Perhaps the most striking feature of the shield is the very large dorsal sensory field. It reaches from the pineal plate almost to the hinder border and is fan-shaped so that the posterior angle almost fills the median projection of the shield. The antero-lateral margins are slightly convex and the blunted lateral angles are roughly right angles. The length is 1·5 cm. and the breadth a little more.

The naso-hypophysial area is very well preserved and shows an interesting feature in that it is very short instead of the usual inverted key-hole pattern. The opening, which has a smooth raised rim, is 1·7 mm. long and on average 0·5 mm. wide, and clearly it would seem to represent only the anterior, hypophysial component. A short, well-defined suture runs for 1·5 mm. from the opening, backwards, with the fine but strongly marked ornamentation of intertwined elongated tubercles covering the area and arranged on either side of it : thus far there is no indication of a separate nasal opening and it is likely that none existed, the opening serving for both. This opening is in fact further back than usual, on the front slope of the nasal prominence instead of in the depression in front. The internal casts of this area may be seen in the type-specimens of *B. lankesteri* and *B. anglica* (see Stensiö, 1932, pl. 48), and

FIG. 37. *Benneviaspis salopiensis* sp. nov. Imperfect cephalic shield. A, Naso-hypophysial area, much enlarged. B, Longitudinal section through same. The holotype. Besom Farm Quarry. P.29721. × 1·5.

indicate the same arrangement. The supposed existence of the independent nasal opening in this genus is probably due to the shearing off of the top of the eminence.

The left sensory field is faintly indicated and is seen to be narrow with a small postero-medial projection.

The ornamentation cannot be made out except around the naso-hypophysial aperture, as described, and along the margin where it consists also of minute reticulated ridges or tubercles.

REMARKS. This species is very clearly marked by the shape and size of the median dorsal sensory field alone. Both the previously described English species, *B. lankesteri* and *B. anglica*, as well as the three from the Red Bay Series of Spitsbergen have narrow dorsal fields, whereas the three from the later Wood Bay Series have wide fields, although not so large as that of *B. salopiensis* nor of the same shape (see Stensiö, 1932 : 152, pls. 47–49 ; text-figs. 55, 56 ; Wangsjö, 1952 : 446–467, pls. 68–75, text-figs. 77–84). This is in keeping with the high Dittonian age of these beds (see Westoll, 1951 : 12, table iii).

UNDETERMINED CEPHALASPID

A single fragment of a cephalaspid shield, measuring 1·0 × 0·75 cm. from Lower Ingardine Ford (P.33794), indicates the occurrence of another cephalaspid from these beds.

The specimen is partly in the form of an impression of the outer surface which shows the superficial layer divided by inter-areal canals and bearing numerous large, smooth, flattened, oblong tubercles, some over 1 mm. long. The basal layer is entirely lost and where the substance is preserved it shows the radiating canals with occasional casts of the ascending canals, etc.

The specimen most probably belongs to a species of *Cephalaspis* itself. Tuberculated fragments of this type have been obtained at Upper Overton Quarry (P.30079–80).

Order THELODONTI

An examination of the residue from the matrices of a few of the localities by Mr. H. A. Toombs has shown, surprisingly, that thelodonts were probably as widespread in these beds as they are in the lower series. So far only samples from Besom Farm Quarry, Upper Overton Quarry, Prescott Mill and Lower Ingardine Ford have been examined and minute scales have been found at each. The expectation now is that they will be found wherever residues are searched. A preliminary examination shows that scales resembling those of both *Thelodus* and *Lanarkia* were present, the scales being very similar to specimens described from the Upper Silurian Beyrichienkalk (Gross, 1947).

This is the latest occurrence of the group outside Spitsbergen. From Northwest Spitsbergen Ørvig (1957 : 288) has recorded thelodont scales from various horizons in the Red Bay Series, and from the Kapp Kjeldsen Division of the Wood Bay Series, which may be comparable in age with the present series (Føyn & Heintz, 1943 : 47). Ørvig (1957) also describes and figures a number of scales, mostly with very large openings to the pulp-cavity, from the south end of Spitsbergen, which on still uncertain stratigraphical grounds, he considers to be even younger, possibly Middle Devonian.

Class GNATHOSTOMATA

Order ACANTHODII

That Acanthodian fishes, like the thelodonts, were present in numbers in these beds cannot be doubted. So far residues have yielded isolated scales at Besom Farm Quarry and Upper Overton Quarry. An asymmetrical carcharinid-like tooth of the *Plectrodus* type, 3·0 mm. high, a little more in length and less than 1 mm.

thick, with sharp cutting edges, also comes from the Besom Farm Quarry (P.28903; Pl. 45, fig. 3), along with five isolated spines of varying sizes. A sixth spine (P.29382) was found at The Gore, near Loughton Church. These six spines clearly show four or five different types of ribbing and probably belong to as many different species. That they do belong to Acanthodians and not to primitive sharks is a reasonable assumption on account of their age, in spite of their similarity in structure (Gross, 1940 : 7).

The spines are distinguished as follows :

(1) P.29082. 2·2 cm. long (slightly imperfect). Symmetrical. A very broad anterior median rib and four broad smooth lateral ribs in each side with narrow shallow grooves. With central cavity and shallow ventral groove, at least at tip.
(2) P.29083. 2·2 cm. long (slightly imperfect). Probably symmetrical. No median rib. Eleven or more sharp narrow smooth ribs divided by deep wide grooves. Large cavity.
(3) P.28887. Fragment 0·9 cm. long. Similar to (1).
(4) P.29081. Fragment of large spine, triangular in section, 2·7 cm. long and 0·8 cm. deep. Possibly asymmetrical. Large anterior median ribs and four widely and differently spaced, very smooth narrow ribs. Very large cavity.
(5) P.29089. 10 cm. long (almost complete). Rounded, no median rib, twelve or more appressed nodular ribs. Small cavity and open posterior groove.
(6) P.29382. Broken fragment 0·7 cm. long. ? Symmetrical. Broad anterior median rib with six moderately wide ribs and similar grooves. Large cavity. The Gore.

Nos. (1), (2), (4) and (5) are very distinct and clearly different from the other species described and have been named accordingly. No. (6), although different from the other spines is too fragmentary for description.

Genus *ISCHNACANTHUS* Powrie, 1864

Ischnacanthus (?) anglicus sp. nov.

(Pl. 45, fig. 4)

Diagnosis and description. This small slender spine now measures 2·2 cm. in length with about 0·2 cm. missing. It is straight and symmetrical except for a stepped fault near the base which from the local thickening of the ribbing is clearly due to damage healed during lifetime. It is attached along most of its hinder margin, except near the missing tip, which was free and shows a wide shallow posterior groove with no denticles and a circular central cavity, relatively small distally, but increasing posteriorly towards the open base. There is a broad, smooth and rounded median anterior ridge, on each side of which are four broad smooth ribs separated by deep and narrow grooves. The two posterior ribs are much narrower than the other two. The inserted portion is 0·4 cm. long and shows very fine ribbing. The line and angle of insertion was at about 45°, as shown by the line of demarcation. This, with its sharpness, suggests that it is a posterior dorsal or anal spine (cf. Watson, 1937 : 78, text-fig. 10).

Holotype. A small isolated fin-spine (P.29082, No. 1 above).

Material. In addition to the holotype a fragment of large spine (P.28887, No. 3); 0·9 cm. long.

Locality. Besom Farm Quarry.

Remarks. In spite of its simplicity of design, this little spine differs from its recorded contemporaries and has therefore been given a new specific name. It is perhaps nearest to *Onchus overathensis* Gross (*O. maior* Gross, 1933*a* : 65, pl. 5, fig. 9, text-fig. 11; 1937 : 67, pl. 8, fig. 8; text-fig. 29) but the anterior median ridge is wide and flatter and there are fewer lateral ribs. The general pattern agrees with that seen in *Ischnacanthus*, e.g. *I. gracilis*, (P.1344, P.6995, P.11165), and to that genus it is tentatively assigned.

Genus *ONCHUS* Agassiz, 1837

Onchus wheathillensis sp. nov.

(Pl. 45, fig. 5)

Diagnosis and description. A small slender spine lacking both the tip and the inserted portion. As preserved it measures 2·2 cm. It is attached along its length by the back and right side. It has a large cavity, and is apparently symmetrical, i.e. a median fin-spine, and is slightly arched. The ribbing is narrow and sharp but smooth and the ribs are separated by deep and wide grooves. There is no continuous anterior median ridge but the foremost rib dichotomizes at intervals and on alternate sides, and this is also to be seen in the finer posterior lateral ribs. The largest number seen on the exposed surface is twelve but it may be still greater.

Holotype. A small isolated fin-spine (P.29083, No. 2 above). The only specimen.

Locality. Besom Farm Quarry.

Remarks. The ornamentation is not unlike that in some spines referred to *Onchus* but it is deeper and finer.

"*Onchus*" *besomensis* sp. nov.

(Text-fig. 38)

Diagnosis. Large, triangular, laterally compressed, hollow spines with smooth sides decorated with four widely-spaced flat, narrow, smooth, longitudinal ridges, spaced 1 : 1 : 2 : 2 to anterior margin, which is acute distally.

Holotype. Fragment of large spine (P.29081, No. 4 above). The only specimen.

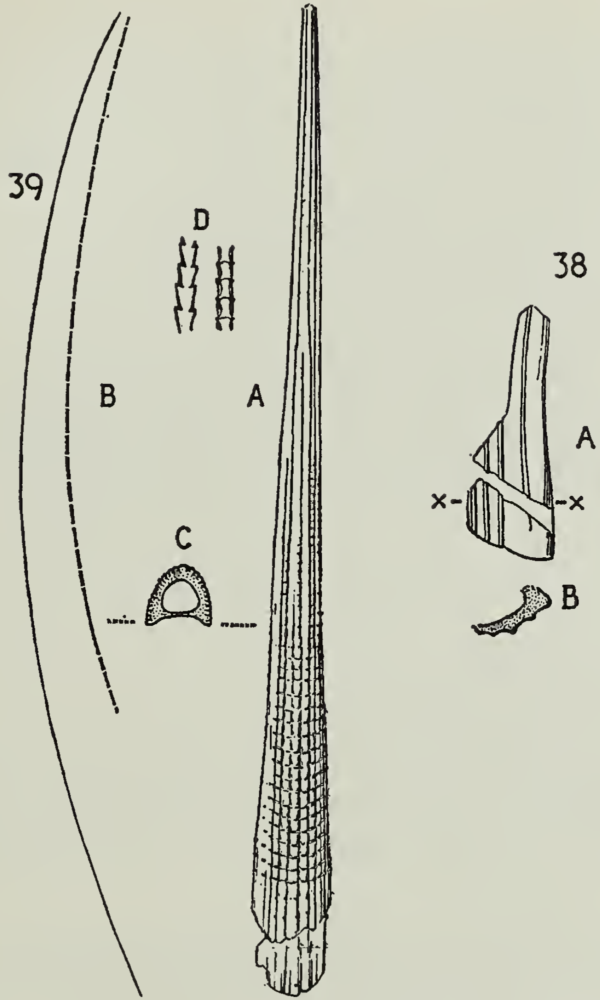


FIG. 38. *"Onchus" besomensis* sp. nov. Fragment of fin-spine. A, side view. B, cross-section at *x–x*. The holotype. Besom Farm Quarry. P.29081. × 1·3.

FIG. 39. *Nodonchus bambusifer* gen. et sp. nov. Dorsal fin-spine. A, anterior view. B, side profile. C, cross-section. D, ornamentation on ridges, further enlarged from the proximal end (left) and the middle. The holotype. Besom Farm Quarry. P.29089. A–C, × 1·3.

LOCALITY. Besom Farm Quarry.

DESCRIPTION. This fragment (Text-fig. 38) is 2·7 cm. long, but is no less than 0·8 cm. wide, and is probably from very near the base. The margin is slightly sigmoid, probably due to *post-mortem* distortion. It is acute distally, the two sides being at a little more than 45° to each other. There are four narrow, widely spaced ribs preserved and the end of a fifth forms the anterior edge for a short way, but then disappears running inwards towards the next rib, while the edge begins to broaden. The next rib becomes wider and broadens and also disappears before reaching the end of the fragment. It is separated from its neighbours by twice the distance between the next three.

The internal cavity is very large. Whether this spine belonged to a median or a paired fin is not clear. Judging by the relative sizes of Acanthodians and their spines, the fish was of the order of 30–50 cm. long.

Remarks. The low narrow ribbing and its arrangement on this large spine are characteristic and confusion with other known contemporary forms is not likely. It is referred to " *Onchus* " merely for convenience.

Genus ***NODONCHUS*** nov.

Diagnosis. Slender tapering spines gently arched with a single, large internal cavity and wide posterior groove apparently without marginal denticles; ornamentation of numerous rounded, closely noded ridges.

Type species. *Nodonchus bambusifer* sp. nov., the only species.

Nodonchus bambusifer sp. nov.

(Text-fig. 39)

Diagnosis. As for genus.

Holotype. Almost complete spine (P.29089, No. 5 above). The only specimen.

Locality. Besom Farm Quarry.

Description. The length of the spine, as preserved (Text-fig. 39) is 9·6 cm., but the extreme tip is missing, and the proximal end is so imperfect that the method of attachment is unknown. In the proximal region the spine is somewhat splayed but soon becomes more compressed laterally and tapers evenly to the distal end which has about one-fifth of the proximal breadth. The pronounced curvature is also even.

The surface is ribbed lengthwise with numerous ridges, over 30 in number near the proximal end, and finest on the sides where they gradually fuse in pairs as the breadth of the spine decreases, until less than a dozen are to be seen near the tip. These ribs are separated by deep but very narrow grooves, and are ornamented throughout with nodes, not unlike those on a bamboo (whence its trivial name). The nodes occur at short intervals which at first tend to get shorter distally but then increase somewhat towards the tip, in which direction the nodes themselves become fainter, while down the sides they become more and more oblique.

The posterior face is apparently in the form of a broad, shallow groove, the full width of the spine, and there are no flanking series of denticles on the one very short piece of margin that is preserved. Much of the posterior surface is broken open to show the very large internal cavity which continues throughout the length of the spine.

Remarks. Nodular ornamentation is recorded in *Climatius* (Gross, 1947 : 146, pl. 27, figs. 6–14; text-figs. 30, 31) among accepted Acanthodian genera and in a form-genus *Nodocosta* (Gross, 1940 : 13–14, pl. 1, figs. 8, 9; text-fig. 1F; also as *Ctenacanthus*, Gross 1933*b* : 64, pl. 11, fig. 8). But in the former the spines are all less slender and the noding is only partial, while in both species of *Nodocosta* the spine is straight, certainly much shorter and more laterally compressed, and has a characteristic upper canal above the pulp-cavity. It seems safer to refer it to a form-genus of its own.

Order ARTHRODIRA

Remains of arctolepid arthrodires have been collected at ten localities in the Upper beds of the Clee area. Besom Farm Quarry, Prescott Reaside and Upper Overton Quarry have proved much the most prolific, and at these places the arthrodire remains are associated with those of both the pteraspids described above, *Pr.* (*E.*) *crenulata* and *Pt.* (*C.*) *leachi*.

Altogether there are some 50 specimens, but all are imperfect and most are the fragmentary isolated plates of small animals. All are ornamented with tubercles, the form and pattern of which is seldom distinctive, so that associating the fragments into species is most difficult, especially where two or more forms occur together as they clearly do at both Besom Farm Quarry and Prescott Reaside. It is, nevertheless, certain that at least six or seven species occur in these upper Dittonian deposits, and five are represented by characteristic and describable plates.

Only one is a known species, *Kujdanowiaspis anglica*, which unexpectedly survives from the earlier strata; a second is a diminutive form of the same genus, based on a spinal plate. The other three species described are also largely based on single plates, but they present such peculiar features that each doubtless represents a new genus. One is a large anterior lateral with which nothing else can be associated, but type-specimens of the other two, like that of the new *Kujdanowiaspis* are small plates accompanied by numerous other specimens which are difficult to sort out among the species.

Genus ***KUJDANOWIASPIS*** Stensiö, 1942

Kujdanowiaspis anglica (Traquair)

(Text-figs. 40–43)

Material. Eight specimens, including parts of two anterior ventro-lateral plates, a scute and possibly part of a small skull-roof.

Localities. Besom Farm Quarry; Prescott Reaside; Newton Dingle 1; and Lower Ingardine Ford.

Description. Three specimens only are worth special attention.

The first specimen, from Besom Farm Quarry, is the imperfect impression with fragments of the plate of a right anterior ventro-lateral (P.28893; Text-fig. 40). It is a little distorted and lacks almost all the edges and the whole of the posterior outer quadrant. Nevertheless, in size and ornamentation it resembles the impression of the right anterior ventro-lateral plate described and figured upside down by

Woodward (1891 : 298, pl. 8, fig. 8), and the impression of three other specimens of the same part, all from the earlier beds at Heightington (Nos. 38032*c*, 37388*c* and P.16032). The ornamentation clearly comes within the range of variation in the species as now understood. As preserved, this plate is approximately 4 cm. square.

The second specimen is a small plate from Prescott Reaside, shown magnified in Text-fig. 41. Its maximum length is 1·0 cm. and breadth 0·7 cm., but the outline is peculiarly irregular, although apparently the specimen is complete. It is convex in both directions, with a well-marked, elongated, smooth, median spine projecting above the tubercular surface, the pattern of which is asymmetrical. The spine has a concave hinder margin. A very well-marked canal pierces the plate from below and seems to pierce the concave hinder margin of the spine on the upper surface. It is clearly a lateral line scale, and if correctly assigned to this form, the only one recorded. Similar but symmetrical and unpierced scales (presumably median ridge-scales) are known from Podolia (P.29222–23), while Denison (1958 : 482, text-fig. 93) has described such plates as "posterior dorsals" in the American genus *Aethaspis*.

The third specimen is the anterior end of a small skull-roof from Newton Dingle 1 measuring just over 2 cm. across the back of the orbits (Text-fig. 42). The ornamentation is very fine, finer than that on an even smaller specimen from Bryn Arw, near Abergavenny (Text-fig. 43). While its attribution is not certain, it probably comes within the wide limits of variation of this species.

The other fragments are of little account, except as distribution records.

REMARKS. These occurrences represent a considerable increase in the geological range of this species, and it is the only form known to be common to both upper and lower beds.

Kujdanowiaspis willsi sp. nov.

(Pl. 46, figs. 1, ? 2 ; Text-figs. 44, 45)

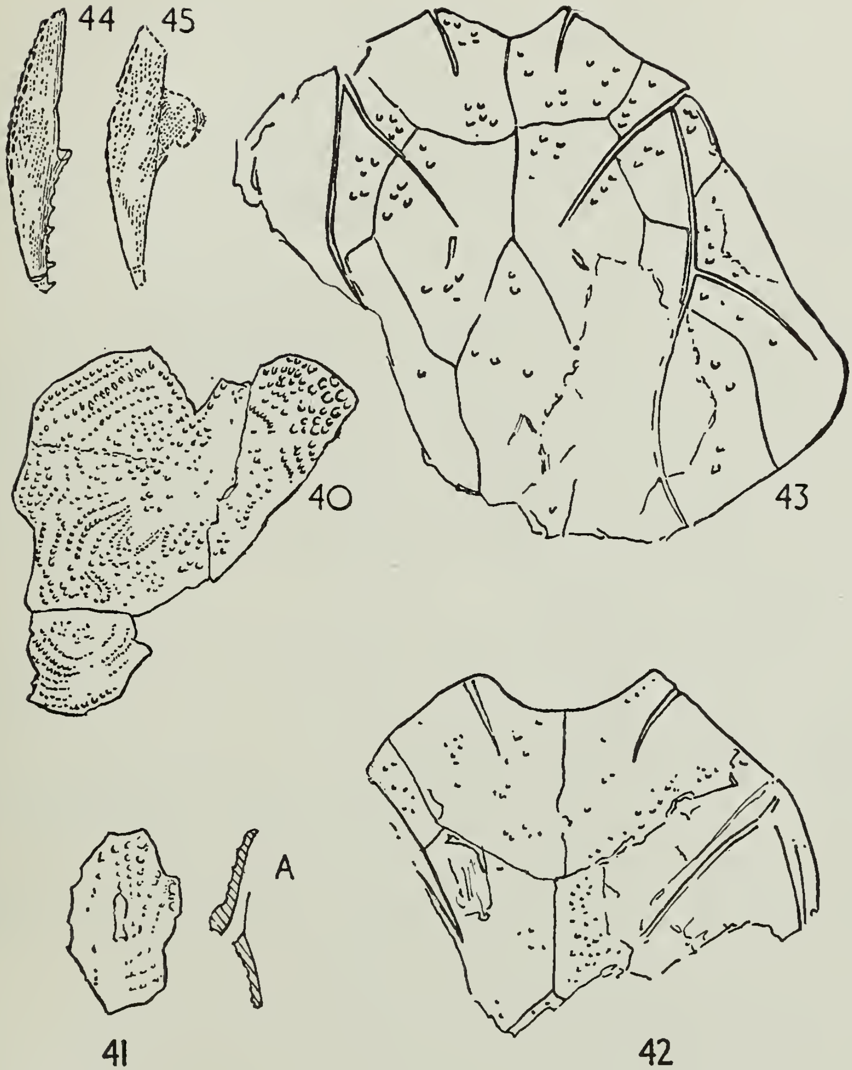
DIAGNOSIS. A small species of *Kujdanowiaspis* represented by a left spinal plate measuring 2·5 cm. in length, the attached and free parts being about equal. Rows of enlarged, elongated tubercles, arranged alternately along outer margin, about seven rows in front, the number decreasing to the rear, finally passing into a single continuous ridge. Denticles on inner free margin about seven in number, very large, recurved and thorn-like distally, well spaced and decreasing forwards in height to low bosses. Ornamentation on body of spine consisting of fine closely appressed oval tubercles, arranged more or less in longitudinal lines.

HOLOTYPE. A left spinal plate in counterpart (P.28913–14).

MATERIAL. Apart from the holotype some doubtfully associated specimens include a left central plate in counterpart (P.28889–90).

LOCALITY. Besom Farm Quarry.

DESCRIPTION. The spinal plate as preserved (Pl. 46, fig. 1 ; Text-figs. 44, 45) measures 2·5 cm. in length, with the distal end naturally fractured. There is still a little missing, the whole being originally about 3·0 cm. measured along the outer margin, of which about half is free spine. The outer margin is gently convex, the



Kujdanowiaspis anglica (Traquair)

FIG. 40. External impression of imperfect right anterior ventro-lateral plate. Besom Farm Quarry. P.28893. × 1·2.

FIG. 41. Lateral line scute,. A, longitudinal section. Prescott Reaside. P.29165–66. × 2·4.

FIG. 42. Anterior end of small skull-roof. Newton Dingle 1. P.29760. × 2·4.

FIG. 43. Imperfect small skull-roof. Bryn Arw, near Abergavenny. P.27190. × 2·4.

Kujdanowiaspis willsi sp. nov.

FIG. 44. Left spinal plate. The holotype. Besom Farm Quarry. P.28913. × 1·6.

FIG. 45. Counterpart of same specimen showing ventral surface. P.28914. × 1·6.

inner even more slightly concave and starting from a slight projection which is grooved to receive the lower posterior angle of the anterior lateral plate. Immediately in front of this lower projection the plate has its maximum breadth, 0·5 cm. The upper face is rather more convex than the undersurface. The latter is shown in the counterpart as an impression to which is attached part of the anterior ventro-lateral plate. Although their common margin is easily determined by slight differences in size and alignment of the ornament, these two plates are completely fused together, whereas the upper margin of the spine, to which the missing anterior lateral plate was attached, is rounded off. This piece of the anterior ventro-lateral plate is quite flat.

The spine on both surfaces is finely and closely tuberculated, the tubercles being low, smooth and oval, closely appressed and tending to run in lines roughly along the length of the spine. The narrow interspaces are usually slightly crinkled.

The tuberculations on the anterior ventro-lateral fragment are even finer and arranged in more definite lines running at an acute angle to those on the spine. The long outer margin of the latter bears along most of its length a number of rather indefinite rows of large elongated tubercles. The tubercles are closely spaced and generally alternate as between rows, of which there are seven or eight in front, but the number is gradually reduced towards the tip, near which the series is reduced to a simple continuous ridge. The individual tubercles are smooth, and the largest are 1 mm. long and 0·4 mm. wide.

On the mesial side of the spine is a row of conspicuous, widely spaced denticles. Distally they are relatively large and thorn-like, up to 1 mm. in height and about the same across the base, but they become lower and blunter towards the pectoral area where they disappear. There is evidence of seven on the spine but as the tip is missing, there were doubtless one or two more.

One other specimen from Besom Farm Quarry is very tentatively assigned to this species on account of some similarity of ornamentation. This is a left central plate, in counterpart (P.28889–90; Pl. 46, fig. 2). It is six-sided, although the truncation of the posterior angle may be an individual variation. Four of the sides, that is all but the anterior side and the short truncated end, are practically equal. The maximum length is 1·0 cm., the breadth, 0·75 cm. The surface shows the short end of the central sensory groove coming in from the front left side but there is no sign of the middle and posterior pit-lines.

The surface shows well the ornamentation especially in impression on the counterpart. The tubercles are smooth and rounder than in the holotype and the pores are more conspicuous. It is only here and there that the actual outer layer is preserved on the positive part, for otherwise an under layer of similar pattern but often on a smaller scale is shown.

Remarks. This small species, named after Professor L. J. Wills who first drew the author's attention to the fauna, is distinguished from *K. anglica* by the generally finer ornamentation combined with relatively larger marginal rows on the spinal plate, and in the relatively large size of the spinal plate itself. Of two spinal plates in the Museum collection of the older species, one (P.16193) is a juvenile half the size of that of *K. willsi*, the other an adult (No. 37388*a*) four times as large, and in neither are the tubercles nearly so conspicuous or elongated. Moreover, in the small spine the free portion is only slightly greater than one-third of the total length, and the other, although lacking the tip, is proportionately stout.

Genus *OVERTONASPIS* nov.

Description. This new genus is based on a single large isolated right anterior lateral plate from Upper Overton Quarry (Pl. 45, fig. 6; Text-fig. 47), collected by Dr. H. W. Ball, after whom the type-species is named. Except for a notch along

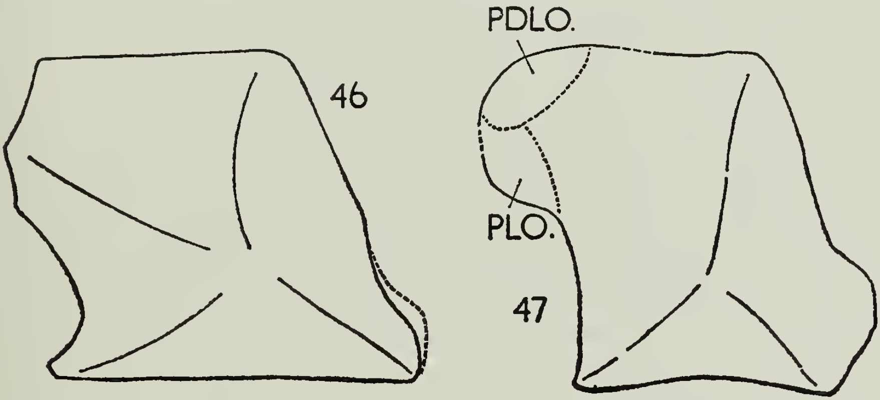


Fig. 46. Outline of internal impression of anterior lateral plate of *Kujdanowiaspis*. The broken line shows the shape of the apron when flattened. Podolia. P.18241. × 1·5.

Fig. 47. Outline of anterior lateral plate of *Overtonaspis billballi* gen. et sp. nov. Upper Overton Quarry. P.29272. × 1·5. *PDLO*, overlap of posterior dorso-lateral plate; *PLO*, overlap of posterior lateral plate.

the upper margin and some cracks it is outwardly complete, but its inner face is defective, so that only the area overlapping the posterior dorso-lateral and posterior lateral plates are to be observed. It is 3·1 cm. in maximum height and a little under 4·0 cm. in breadth.

Compared with the excellent outline restorations of comparable plates in other Arctolepids figured by Denison (1958 : 525, text-fig. 110) it is remarkable for the simplicity and squareness of its outline. The dorsal and ventral margins, both slightly emarginate, are roughly parallel, but more noteworthy still is that the upper half of the slightly inturned apron is parallel with the vertical lower half of the hinder margin which borders the pectoral fenestra. The upper part of the posterior margin starts at right angles to the lower and is almost semicircular. The lower half of the anterior margin forms a blunt angle approximately on a level with the centre of ossification, which is 0·8 cm. from the ventral margin and 1·3 cm. from the hinder margin. The exposed surface is divisible into three very unequal areas which meet at the centre of ossification. The largest area, comprising most of the surface, is separated from the apron in front by a line marked by an abrupt change in ornament and a less obvious change in plane running from the top anterior corner to the centre of ossification ; and from the basal area by a slight ridge with change in tuberculation running from the centre of ossification to the rectangular posterior lower corner. The apron and the basal area are separated by a low rounded ridge leading from the centre of ossification to the obtuse anterior lower corner, so that the basal area is almost a low isosceles triangle.

The apron gently slants inwards, especially the lower part which is also slightly hollow, while the basal area is slightly concave, the bottom margin of the plate being incurved. Curiously the whole of the main area is somewhat concave and markedly so in the rounded dorso-posterior area, where the margins are definitely outwardly turned. The extent to which this is due to distortion is not clear, but it is not entirely so.

The ornamentation is very distinctive. It is, as is generally the case, tubercular, but the tubercles are absolutely smooth, and so, as a rule, are the interspaces. The largest tubercles are pointed and mammiform, and arranged roughly in rows parallel with, and near to, the dorsal and posterior margins. They gradually decrease in size towards the centre of ossification. On the basal area and the upper part of the apron the tubercles are almost granular, but on the lower, wider part of the apron they are somewhat larger and triangular with the apices pointing downwards and outwards, exactly as in *Williamsaspis* (White, 1952 : 265, pl. 28, fig. 1).

A fragment 1·5 cm. long (P.29274) from the same locality shows similar but small smooth denticles.

Diagnosis. The genus is temporarily defined as including Arctolepids of moderate size in which the anterior lateral plates have approximately parallel upper and lower borders with the lower hinder and upper front borders at right angles in direction, the upper half of the hinder border being in the form of a semicircular projection, the lower front, obtusely angular. Ornamentation tubercular, the tubercles and interspaces being quite smooth, and the largest tubercles, on the upper hinder projection being long and mammiform.

Type Species. *Overtonaspis billballi* sp. nov., the only species.

Overtonaspis billballi sp. nov.

(Pl. 45, fig. 6 ; Text-fig. 47)

Diagnosis. As for genus.
Holotype. A right anterior lateral plate (P.29272), the only specimen.
Locality. Upper Overton Quarry.

Genus ***PRESCOTTASPIS*** nov.

Description. This genus is based on a small posterior lateral plate (Text-fig. 48) from Prescott Reaside with which are associated ten or a dozen fragments from the same locality, but of these only three, part of a left posterior dorso-lateral plate

(P.29153), an even smaller piece of a right posterior ventro-lateral, and a scute are worth description. Obviously the association of such small fragmentary plates can only be tentative but constructional features seem to tie the plates mentioned together. A left posterior ventro-lateral plate without ornament is also described here.

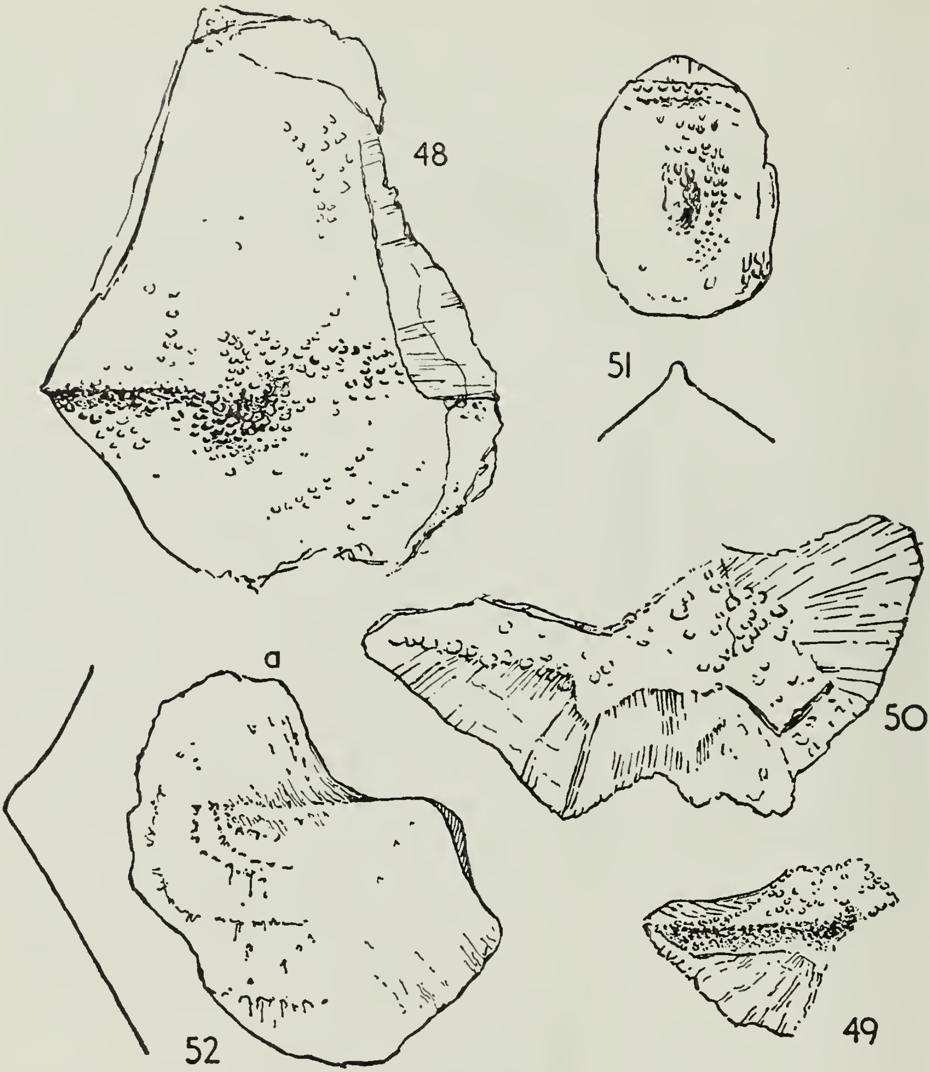
The posterior lateral plate, from the right side, is most remarkable (Text-fig. 48) and quite unlike any other comparable plate (cf. Denison, 1958 : 526, text-fig. 111), with the exception of that of *Williamsaspis* (White, 1952 : 259, pl. 26, fig. 2 ; pl. 27, fig. 2 ; text-figs. 7, 11) which it resembles in that its height (1·5 cm.) exceeds its maximum length or width (1·2 cm.). The latter occurs 1 cm. from the short (0·5 cm.) and somewhat convex dorsal margin. From the top the two sides slope gently outwards, the posterior gently concave and grooved (presumably for attachment of the skin), and the anterior irregularly sigmoid and marked by a right-angled area of overlap. This finishes in a short, deep groove at the maximum breadth, which is marked behind by a point rather larger than a right angle. From this posterior angle a conspicuous and undercut ridge runs forward and passes into a well-marked boss towards the middle of the plate. The lower part of the plate is certainly imperfect, for it lacks the posterior ventro-lateral overlap. As preserved it is nearly semi-circular. The angle between the lower and upper parts is small, about 10°. The ornamentation consists of rather conical, slightly fluted tubercles with the usual wrinkled interspaces and pores.

Associated by reason of the similarity of the ornament is a fragment consisting of the ventral median extension of a right posterior ventro-lateral plate (Text-fig. 49). It measures 0·7 cm. in length with a maximum breadth of 0·45 cm., of which half is occupied by the area overlapped by the left plate. This is the usual overlap, but it must have been relatively very large indeed—again after the style of *Williamsaspis*. The upper free margin is concave. Like the first specimen this plate has a sharp ridge dividing the ventral and lateral surfaces, which passes forwards into a boss.

Much less certain in its attribution to this genus is a nearly complete left posterior ventro-lateral plate (Pl. 46, fig. 4 ; Text-fig. 52). It is 1·1 cm. in height with a maximum width of rather less than 1 cm. The whole of the ornament has disappeared and the surface is smooth save for structural features. The wide ventral part is divided from the small lateral flange by a pronounced ridge, not unlike that of the two previous plates, but the association is very tentative.

More confidently attributed to this form is a left posterior dorso-lateral plate of which the dorsal part has been destroyed (Text-fig. 50). The lower margin, with deep areas overlapped by the two lateral plates, is intact and so is the supposedly posterior margin, but the external ornamented layer has been removed from the hinder region. It is peculiar in having a substantially longer overlapped area for the anterior lateral plate than for the posterior (cf. Denison, 1958 : 522, text-fig. 109), but that the plate is properly identified and orientated is confirmed by the narrow upper end of the first plate described, the upper end of which fits admirably the hinder area.

The outer surface is much mutilated except for a strip immediately above the



Prescottaspis dineleyi gen. et sp. nov.

FIG. 48. Right posterior lateral plate. The holotype. P.29152. × 5.

FIG. 49. Fragmentary right posterior ventro-lateral plate. P.29156. × 4·8.

FIG. 50. Fragmentary left posterior dorso-lateral plate, possibly of this species. P.29153. × 4·8.

FIG. 51. Median body-scute with cross-profile below. P.29267. × 5·2.

FIG. 52. Imperfect left posterior ventro-lateral plate without surface ornament, possibly of this species, with cross-profile at A. P.29259. × 4·8.

All from Prescott Reaside.

overlapped areas. The ornament is tubercular but coarser and more worn than in the two preceding plates. There is no indication of the lateral line.

The last specimen is of great interest, for it is a median body-scute (Pl. 46, fig. 3; Text-fig. 51). It is bowed from side to side with slightly convex sides, which are, however, imperfect, and has roughly straight posterior and anterior margins. In front there is also a triangular overlapped area, showing that it was one of a continuous series. Whether it overlapped in turn a scale behind it is not clear. There is a low but well-marked median spine. It is uncertain whether it belonged to a dorsal or ventral series. The overall length is 7 cm. and the maximum breadth 4·5 cm. Attention has already been drawn to median body-scutes in the case of *Kujdanowiaspis* above (p. 290).

The ornamentation is very well preserved, consisting of small conical denticles varying in size according to position. Most lean backwards and all show the flutings seen in the previous specimens.

The other specimens from Prescott are doubtful fragments and show little else than indifferently preserved ornamentation.

Remarks. The genus may be defined on the form of the posterior lateral plate, which is most distinctive and clearly shows that the form belongs to at least a family of its own, the Prescottaspidae. Among the other arthrodires from these beds, the ornamentation, with its fluted conical tubercles, is easily distinguished when fresh.

Type species. *Prescottaspis dineleyi* sp. nov., the only species.

Prescottaspis dineleyi sp. nov.

(Pl. 46, figs. 3, ? 4; Text-figs. 48–52)

Diagnosis. As for genus.

Holotype. A right posterior lateral plate (P.29152).

Material. In addition to the holotype, part of a right posterior ventro-lateral plate (P.29156), an imperfect left posterior dorso-lateral plate (P.29153) and a median scute (P.29267) and some fragments.

Locality. Prescott Reaside.

Genus ***WHEATHILLASPIS*** nov.

Description. A fourth genus of arctolepid is represented by a small and imperfect anterior ventro-lateral plate with part of the spinal plate attached, from Besom Farm Quarry (Pl. 46, fig. 5; Text-fig. 53). The anterior margin and part of the inner margin are missing, likewise the tip of the spine. The maximum width of the combined plates is 2·0 cm. The most striking feature is the great size of the pectoral fenestra (*P.F.*) which occupies more than three-quarters of the outer margin of the anterior ventro-lateral plate, from the contact with the spinal plate to the short dorsal extension (*D.E.*). This fenestral margin, to which fragments of the perichondral bone of the scapulo-coracoid are attached, is concave bow-shaped with a blunt middle prominence, the whole lying about 45° to the length of the fish. The dorsal extension behind it was narrow, occupying about half the remainder of this outer margin. How high it extended cannot be judged, but presumably it overlapped the posterior ventro-lateral plate in the manner of Stensiö's (1944: 60, text-fig. 17) restoration of *Kujdanowiaspis*. The posterior margin shows an obtuse angle dividing a short straight outer border from the larger bowed medial border, which passes into the inner margin.

The spinal plate is not clearly marked off from the anterior ventro-lateral but the division can be detected below the anterior end of the pectoral fenestra. It was broad and probably moderately short. The outer margin bears two or more rows of enlarged, well-separated rounded tubercles, but there are no signs of denticles on the inner margin as preserved. The ornamentation on the plates is tubercular, the tubercles being round and generally fine but mixed with even finer papillae with patches here and there of larger tubercles. In a few areas where wear has been less than usual, the tubercles are seen to be faintly striated or fluted.

Two other small plates from Besom Farm Quarry are tentatively associated with the foregoing, chiefly on the grounds of similarity in ornamentation.

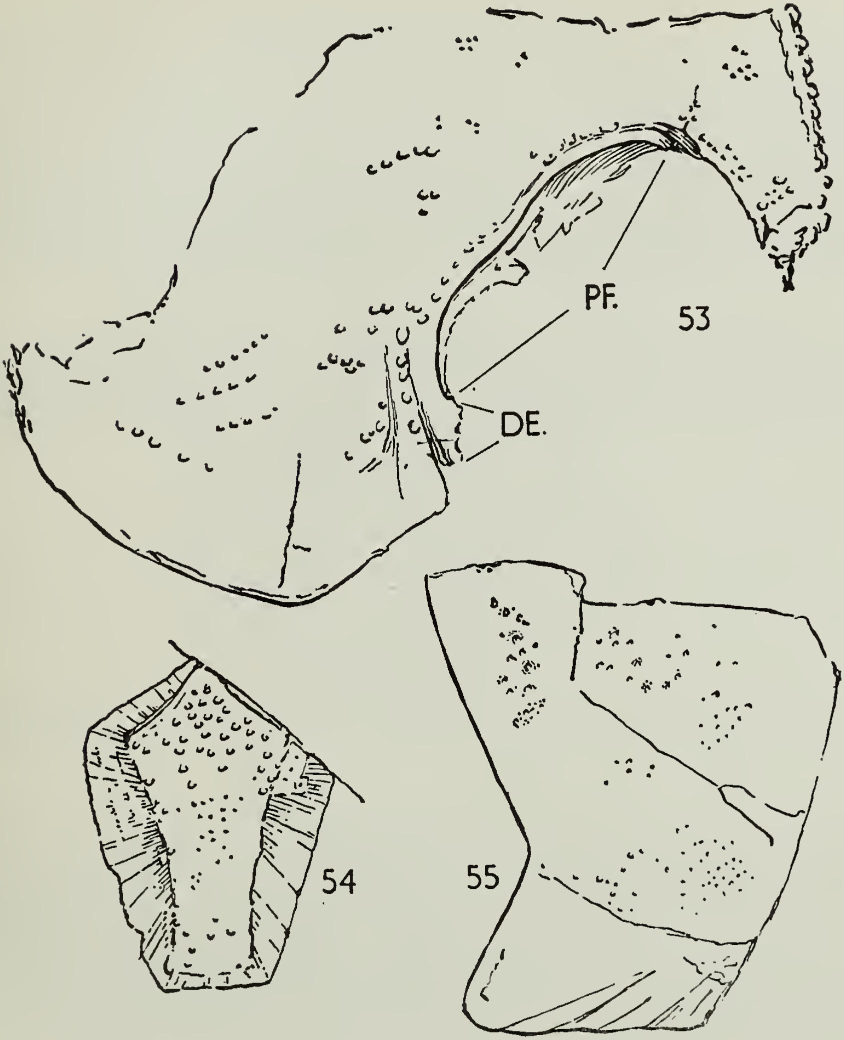
The first is a median ventral plate (Text-fig. 54). It is coffin-shaped, 1 cm. in length and about 0·75 cm. across at its maximum. The lateral overlapped areas are wide and the borders of the ornamented surface gently concave, and so is the supposed right anterior border where the overlap was increasingly narrow (the left is partly cut away). The narrow posterior margin is either straight or gently convex, and there is apparently a very narrow overlapped selvage which, however, may be due to imperfect preservation. The ornamentation is a mixture of fine or very fine rounded tubercles, which occasionally show signs of fluting. The plate is described as an anterior median-ventral, after the style of *Bryantolepis* (Denison, 1958, 533, text-fig. 113) rather than as a posterior plate like that of *Phlyctaenaspis* or *Prosphymaspis* (Gross, 1937: 21, text-fig. 12), but there is no evidence one way or the other.

The second plate, doubtfully referred to this form is an imperfect left anterior lateral (Text-fig. 55). The apron in front is entirely missing and so is the dorsal border. As preserved, the plate measures 1·4 cm. in height with a maximum breadth, along the top, of 1·2 cm. The outstanding feature is the simple angularity of the hinder margin, and the obtuseness of the rounded postero-inferior angle. It is to be matched in none of the plates outlined by Denison (1958: 525, text-fig. 10).

The lower third shows the inner surface, which is much grooved towards the centre of ossification, but the remainder is preserved as an external impression. The ornamentation is finely but variably tubercular, the finest tubercles being towards the lower front and the largest in the top back segments.

The tubercles are well separated with the intervening spaces crinkled or papillated. The smallest are round but become more and more oval with increase in size, and the largest show marked flutings. This ornament comes well within possible variation for the genus and species.

An imperfect right anterior ventro-lateral plate from Upper Overton Quarry (P.30087) may belong to this genus and species, but the critical fenestral margin is too imperfect for certainty. There is also a worn, almost symmetrical scute (P.30086).



Wheathillaspis wickhamkingi gen. et sp. nov.

Fig. 53. Part of left anterior ventro-lateral and spinal plates. *DE*, dorsal extension of anterior ventro-lateral plate; *PF*, pectoral fenestra. The holotype. P.28908. × 5·6.

Fig. 54. Median ventral plate. P.28910. × 4·8.

Fig. 55. Imperfect left anterior lateral plate, largely in impression. P.28911. × 4·8.

All from Besom Farm Quarry.

Remarks. The genus is best defined on the basis of the first specimen, the essential features being the very large, oblique pectoral fenestra (cf. Denison, 1958 : 530, text-fig. 12).

Type species. *Wheathillaspis wickhamkingi* sp. nov., the only species.

Wheathillaspis wickhamkingi sp. nov.

(Pl. 46, fig. 5; Text-figs. 53–55)

DIAGNOSIS. As for genus.

HOLOTYPE. An imperfect left anterior ventro-lateral plate with part of spine (P.28908).

MATERIAL. Apart from the holotype there is a median ventral plate (P.28910), an imperfect left anterior lateral plate (P.28911–12) and more doubtfully still, an imperfect right anterior ventro-lateral plate (P.30087), and a scute (P.30086).

LOCALITIES. Besom Farm Quarry; ? Upper Overton Quarry.

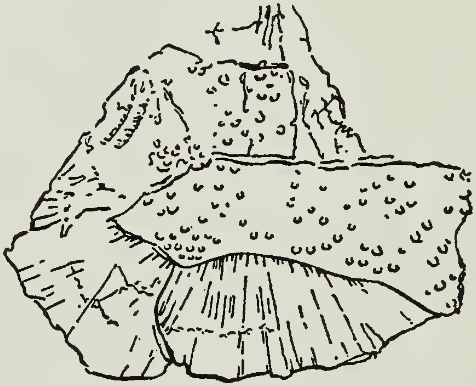


FIG. 56. Gen. et sp. indet. Fragmentary left posterior dorso-lateral plate. Stottesdon Brook. P.28353–54. × 4·8.

UNDETERMINED ARCTOLEPIDS

Among the material that cannot be assigned clearly to one of the species described are two interesting plates worthy of some attention.

Text-fig. 56 shows an imperfect posterior dorso-lateral plate from the left side, from Stottesdon Brook, the only arthrodire fragment from the locality. It is 1·2 cm. in length, but the depth is uncertain for almost all the plate above the lateral line is damaged. The lower part is intact and shows, in contrast to the same plate of *Prescottaspis* (Text-fig. 50), a narrow anterior overlap for the anterior lateral plate. This is normal for the group (see Denison, 1958 : 522, text-fig. 109), but in its imperfect state it does not bear any striking resemblance to the forms figured. Allowing for variation in the species and individuals it comes nearest to the plate in *Kujdanowiaspis* (see Stensiö, 1944 : 60, text-fig. 17A). The tuberculations are of the usual stellate form seen in that genus.

The other specimen of particular interest is a stout, very asymmetrical plate, which clearly seems to be a body-scute, from Upper Overton Quarry (P.29756, Pl. 46, fig. 6). It is an extremely thick plate much wider than deep. The long sides are roughly parallel but the upper is slightly convex and shorter than the lower, which is concave, the length being 1·4 and 1·6 cm. respectively. The depth is 1·0 cm. The anterior end (right of figure) is unevenly sigmoid with a short embayment at the top ; the straight truncation of the convex lower part is artificial. The hinder end is gently convex but broken by a most conspicuous ridge or blunt spine. This striking feature is deeply undercut behind, but above the slope upward is flat and the whole disappears gradually forwards. The ornament is of relatively corase tubercles with crinkled bases arranged roughly parallel with the sides, very much like that in *Kujdanowiaspis anglica*. It may indeed belong to that species, but similar plates have not been recorded elsewhere. The only other specimen of an arthrodire plate from this locality is the anterior lateral of *Overtonaspis*, which has very different ornamentation.

III. FAUNA OF THE FARLOW SANDSTONE SERIES

Only six localities in the Upper Old Red Sandstone of the Clee area have yielded fossils, three being in the Yellow Farlow Sandstone Formation at Prescott Corner, Farlow, Old Lane, and the old Church Quarry, near Farlow, the exact situation of

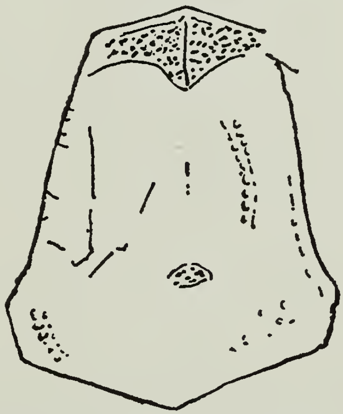


FIG. 57. *Bothriolepis* cf. *hydrophila* (Agassiz). Imperfect posterior median dorsal plate. Church Quarry, Farlow. P.27167. × 1·5.

which is not now known but which was probably in Farlow Bank, a little to the north of the church for the building of which it was opened. The Prescott material, from a roadside section, is extremely fragmentary, but it can be related to the more extensive material from Church Quarry from which Woodward (1891 : 231, 249, 366) recorded *Bothriolepis macrocephala*, ? *Phaneropleuron* and *Sauripterus anglicus*. The fragments yielded by the three localities in the Grey Farlow Sandstone Formation at Prescott, Old Lane and Walton Brook 1 and 2, are very poor.

Class GNATHOSTOMATA

Order ANTIARCHI

Genus ***BOTHRIOLEPIS*** Eichwald, 1840

Bothriolepis macrocephala Egerton

Both A. S. Woodward (1891 : 231) and Stensiö (1948 : 511) have suggested that this species was related to *B. hydrophila* (Agassiz), either as a variety or as the young, but no specimens of a larger species were recorded from Church Quarry, Farlow, the only locality from which *B. macrocephala* was known. Curiously enough, there was in the collection at that time, a very fair posterior median dorsal plate that, in its shape, might very well belong to *B. hydrophila* (Text-fig. 57) ; and now at Prescott Corner fragmentary remains also of a large species, unfortunately too incomplete for identification, have been found associated with very small isolated anterior and posterior median dorsal plates only 6 to 8 mm. in length. It seems probable that this species is based on the young of the larger species, but the identity of the larger species cannot be established for certain ; and although it may be *B. hydrophila*, the ornamentation on the larger plates is retiform rather than nodular, as in other species, and so *B. macrocephala* may be distinct, although attaining a much larger size than had been supposed.

Order CROSSOPTERYGII

Family Holoptychiidae

Genus ***PSEUDOSAURIPTERUS*** nov.

Sauripterus anglicus was described by A. S. Woodward (1891 : 366, pl. 16, figs. 4–6) from two slabs, each showing a number of isolated scales (P.200, P.200*a*), and one a laniary tooth ; a large isolated scale (P.200*b*) and the impression of an isolated tooth (P.201) which was in fact the counterpart of the tooth on the type slab (P.200). There are a number of other specimens not described. All are from Church Quarry, Farlow and came to the Museum in the Weaver-Jones Collection in 1880. Part of the counterpart of the type slab was acquired with the collection of the Rev. P. B. Brodie in 1895. The scales were described by Woodward as " robust, the exposed portion ornamented with coarse, sparsely and irregularly arranged tubercles ", but of the figured scales from the type slab pl. 16, fig. 6 shows only the broken middle layers and the other (pl. 16, fig. 5) the undersurface. Part of the type slab and the whole of the counterpart and the second slab have been etched in hydrochloric acid to remove the broken middle layers, leaving very clear impressions of both upper and lower surfaces (Pl. 47, figs. 2–5), which show that the supposed external ornament of tubercles are tubercles pierced by pores on the undersurface of the scale ; while the true ornament of the exposed area of the upper surface is seen to consist of fine simple ridges, running lengthwise across the scale, but fading out before reaching the hinder margin. The ridges are generally well separated and roughly parallel with one another, although occasionally meeting, and in some of the scales from Prescott Corner are broken into short lengths (P.28967). On the relatively coarse matrix only occasionally can fine transverse wrinkles be detected (P.27173) in the valleys between. Behind the ridges on the overlapped portion of the scale are short radiating lines of tubercles, usually dimpled (P.27172), as in *Glyptolepis* (cf. Jarvik, 1950 : 111, text-fig. 33 ; Ørvig, 1957 : 386, text-fig. 4).

Several of the scales show on the upper surface the external branches of the lateral line, which can be seen on each scale just behind the radiating tubercles on the overlapped area as broad, rapidly deepening grooves that disappear below the surface at the beginning of the exposed area, at the same time giving off six or more shallow radiating canals (seen in the photographs, Pl. 47, figs. 2, 4 as narrow grooves) that sometimes branch still further, the canals ending as well-separated pores on the exposed surface of the scale near the hinder margin. In two scales (one each on P.200*a* and P.7601) the undersurface shows the corresponding exit of the main canal near the hinder margin where it runs backwards and downwards on to the scale it overlaps. A similar, but rather coarser, arrangement can be seen in a single scale of a specimen (No. 41413) of *Glyptolepis leptopterus*, but the groove of the main canal seems longer and deeper.

FIG. 58. Impression of Crossopterygian tooth, counterpart of specimen described and figured as *Sauripterus anglicus* by A. S. Woodward, 1891 : 366, pl. 16, fig. 4. P.201. × 3.

Some of the scales are over 3·0 cm. high and if in proportion to those of *G. leptopterus* would indicate a fish about 120 cm. in length.

Woodward referred this species tentatively to the same genus as the American *Sauripteris* (usually written *Sauripterus*) *taylori* Hall but the scales of that fish, of which three[1] are figured on Plate 48, are very differently ornamented. In any case *Sauripteris* is a Rhizodont, whereas the radiating lines of tubercles on the overlapped part of the scales shown in this fish are deemed by Ørvig (1957 : 391) to be the hall-mark of a Holyptychiid. The new genus *Pseudosauripterus* differs from *Glyptolepis* in respect of its scales to the same degree that the latter differs from *Holoptychius*, in the still finer and simpler nature of the ornament on the exposed surface, and may be defined briefly as follows : Holoptychiid fishes in which the external ornament of the scales consists of fine simple ridges running lengthwise across the scale but disappearing before reaching the hinder border, well separated and roughly parallel with one another but sometimes anastomosing and in some cases broken up into short lengths.

Type and only known species, *Sauripterus anglicus* A. S. Woodward.

[1] For these I am indebted to Dr. Bobb Schaeffer, of the American Museum of Natural History, N.Y.

There are several more fragmentary pieces from Prescott Corner, of which the best is an imperfect cleithrum and clavicle (P.32256).

The associated tooth on the type slab (P.200), which is 1·6 cm. high, 0·7 cm. across the base and split down the middle, was figured by A. S. Woodward (1891, pl. 16, fig. 4) and described as " straight and regularly tapering, moderately compressed ". The counterpart, an external impression (Text-fig. 58) shows the tooth to be very little compressed, and perfectly smooth in the upper half. There are about fourteen deep basal vertical grooves which almost disappear about 0·6 cm. height but which are in fact continued faintly, at first with subsidiary grooves, for

FIG. 59. *Pseudosauripterus anglicus* (A. S. Woodward). Cast of right entopterygoid referred to this species. Church Quarry, Farlow. (See Pl. 47, fig. 1.) P.27176. × 1·5.

some distance before finally disappearing. The wide conical cavity is seen up to 0·9 cm. This tooth has a rather Rhizodont aspect and its reference to this species is questionable.

From the same collection and locality as the type scales and the tooth comes a most interesting specimen not mentioned by Woodward. This is a right entopterygoid, now an external impression, in counterpart (Pl. 47, fig. 1; Text-fig. 59). It seems likely to belong to this fish but there is no comparable material of this family for comparison. The palatine region is wide and the quadrate part a long narrow curved bar, the smooth outer margin of which bordered the wide adductor fenestra, ending in an expansion for the support of the quadrate articulation. The medial or upper border shows a wide overlapped area for seating the palato-quadrate complex, with a triangular ascending process. This area continues in front and then below, for the ectopterygoid, dermopalatine and possibly vomer, showing a rather irregular inner margin. On both upper and lower overlapped borders are wide grooves for branches, presumably of the palatine artery. The whole exposed surface of the bone almost to the hinder end of the bar is covered with fine sharp teeth which increase considerably in size just in front of the outer border of the adductor fenestra. This bone is quite unlike the corresponding element in *Eusthenopteron* (Jarvik, 1954, text-figs. 16, 25) in its slender quadrate ramus and consequently in the shape of the dentigerous area, in both of which it rather strikingly resembles the ichthyostegid *Ichthyostegopsis wimani* Säve-Söderbergh (1932 : 69, pl. 17, fig. 2 ; text-fig. 13) and to a less extent the Rhizodont *Eusthenodon* (Jarvik, 1952 : 66, pl. 16, fig. 2 ; text-fig. 29). On the other hand the upper overlapped margins indicate some agreement with *Megalichthys* and *Eusthenopteron* as figured by Watson (1925 : 247, text-figs. 32–34) with " a series of supra-pterygoid ossicles ", of which the quadrate in *Pseudosauripterus* lies in a long groove ending in an expansion at the articular end. The middle and hinder part of this overlapped area is bent upwards at a considerable angle to the dentigerous area and must have stood almost vertically in the head.

Two very imperfect cleithra (P.28999, P.32256) from Prescott Corner may belong to this species. They show very similar ornament to that in *Glyptolepis leptopterus* (Jarvik, 1949 : 30, text-fig. 9*a*). One shows part of the endoskeletal girdle.

Pseudosauripterus anglicus (A. S. Woodward)

(Pl. 47 ; Text-figs. 58, 59)

Diagnosis. As for genus (only species).

Type specimen. Slab with about a dozen scales and a tooth, partly in impression (P.200), in part counterpart (P.7601, P.201), from Church Quarry, Farlow. The species is based on the scales, of which that figured by A. S. Woodward (1891, pl. 16, fig. 6—see also Pl. 47, fig. 5 of this work) is chosen as lectotype.

Localities. Church Quarry, Farlow and Prescott Corner.

Family Rhizodontidae

Genus ***EUSTHENOPTERON*** Whiteaves, 1881

Eusthenopteron farloviensis sp. nov.

(Text-fig. 60)

Diagnosis. An *Eusthenopteron* distinguished by the shape of the cleithrum.

Holotype. Scattered remains on slab, most probably from Church Quarry, Farlow (P.43444).

Material. In addition to the holotype, two scales from Church Quarry, Farlow (P.27165–6) and a scale (P.28979) with a few doubtful fragments of plates from Prescott Corner.

Description. The holotype is a large slab of yellow sandstone, unlocalized but identical in matrix with those from Farlow, which shows the remains of a medium-sized fish. It includes numerous scales, the anterior part of the tail, part of the vertebral column and the left cleithrum.

The cleithrum (Text-fig. 60) is almost complete, having lost only a little of its dorsal border, and the anterior ventral margin, where it is overlapped by the clavicle, is slightly compressed. It is 8·0 cm. high and has a breadth of 2·5 cm. which does not vary more than 2 mm. from one end to the other and it is not divided clearly into dorsal and ventral parts as in the type species *E. foordi* (cf. Text-fig. 61 ; Jarvik, 1944*b* : 12, text-figs. 3D, 4D), and the posterior margin is almost straight without

Fig. 60. *Eusthenopteron farloviensis* sp. nov. The left cleithrum. *Pr. Cl.* process of cleithrum. The holotype. [Church Quarry, Farlow.] P.43444. × 1.

Fig. 61. *Eusthenopteron foordi* Whiteaves. The right cleithrum (reversed). *Pr. Cl,* process of cleithrum. Scaumenac Bay, P.Q., Canada. P.6797, P.6797*a*. × 1.

the " heel " shown in the Canadian species. Moreover, the process of the cleithrum at the top of the border along the overlap of the clavicle is large and the ventro-median projection less developed.

On the other hand the ornamentation, so far as it can be determined, is the same as in *E. foordi* as shown in P.6797*a*, consisting of vermiculating ridges which become very tubercular on the ventral face, which in life was bent horizontally underneath the fish. This tubercular development is not shown in Jarvik's figures.

There are about 80 cycloid scales, mostly preserved as external impressions. They vary in size from 1·5 × 1·3 cm. to 0·9 × 1·2 cm. The ornament, as in *E.*

foordi, consists of between 16–22 well defined parallel longitudinal ridges and is very different from that seen in *Tristichopterus*, in which the ridges tend to run with the margins of the scales and thus converge along the mid-line (Nos. 42398, 42406). Several scales on the new specimens show the Rhizodont boss on the underside. Two similar scales are in the original collection from Church Quarry, Farlow (P.27165–6).

The remains of the axial skeleton are confined to the neural and haemal spines of the tail region, the whole closely resembling those of *E. foordi*.

The cleithrum and the scales are only slightly bigger than those of specimen P.6797, which has a head-length of 17·5 cm. and would therefore have belonged to a fish of about 80 cm. in total length.

The only other specimens that may belong to this species is a fragmentary impression of a jaw-bone with teeth (P.28965–66) from Prescott Corner, which, with a scale, have already been recorded as *Eusthenopteron* sp. by Ball & Dineley (1952 : 213).

REMARKS. Five species have been referred to *Eusthenopteron*, *E. foordi* Whiteaves from Canada, *E. traquairi* Westoll from Boghole, Scotland, *E. säve-söderberghi* Jarvik from Livonia and *E. wenjukovi* (Rohon) from Russia, with a fifth, *E. ? dalgleisiensis* (Anderson), from Dura Den tentatively added to the list. Of these only in *E. foordi* and *E. ? dalgleisiensis* is the shoulder-girdle known and comparison has already been made with *E. foordi* to establish sufficient distinction, while in *E. ? dalgleisiensis* the rounded form of the cleithrum is even more distinctive (Jarvik, 1950*a* : 28, text-fig. 9A). With the other three species known only by remains of the head no comparison can be made. They, like *E. foordi*, are from beds near the base of the Upper Old Red Sandstone (Westoll, 1937 : 522), but the range of the genus is substantially increased upwards if *E. ? dalgleisiensis* is correctly assigned to this genus (Westoll, 1951 : 12, Table III), since Dura Den is considered to be of Middle Famennien age (Jarvik, 1950*a* : 33).

Order DIPNOI

Genus Indet.

The " impression of a small dental plate (P.198) with five coarsely tuberculated ridges " from Farlow referred by Woodward (1891 : 249, No. P.198) " to *Phaneropleuron* with much probability of correctness " is not clear in its definition. There are indications of a sixth ridge and it might as well be the plate of a dipterine.

IV. ACKNOWLEDGEMENTS

The palaeontological section of this work was in the first place planned merely as an appendix providing information for the main stratigraphical memoir of Drs. Ball and Dineley ; but like Topsy, it " growed and growed ", until it has had to be accorded an almost independent status. Its main purpose is still to serve the stratigraphers, and to that end and under the inexorable pressure of diminishing time, it has been largely restricted to a systematic study of the material provided.

It is to be hoped that in the hurry the servant has not left too much dust under the stratal carpet ; and he is grateful that his tardiness, not entirely the result of inevitable senescence, has been borne with patience.

Discussion with Professor D. M. S. Watson has had its usual fruitful results ; Mr. H. A. Toombs has shown his wonted skill in the preparation of many refractory specimens ; and Mr. R. Baker his customary deftness in converting an almost illegible MS. into an orderly typescript on which Mr. F. M. Wonnacott has exercised his habitual discretion as editor ; and finally Mr. Philip Gurr, during his ephemeral association with the Department, has achieved a welcome degree of excellence in his preparation of the plates ; to all I gratefully acknowledge my indebtedness.

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PLATE 33

Pteraspis (*Pteraspis*) *dairydinglensis* sp. nov.

FIG. 1. Uncrushed rostral region. Hopton Brook 4, Hopton Wafers. P.42360. × 2.

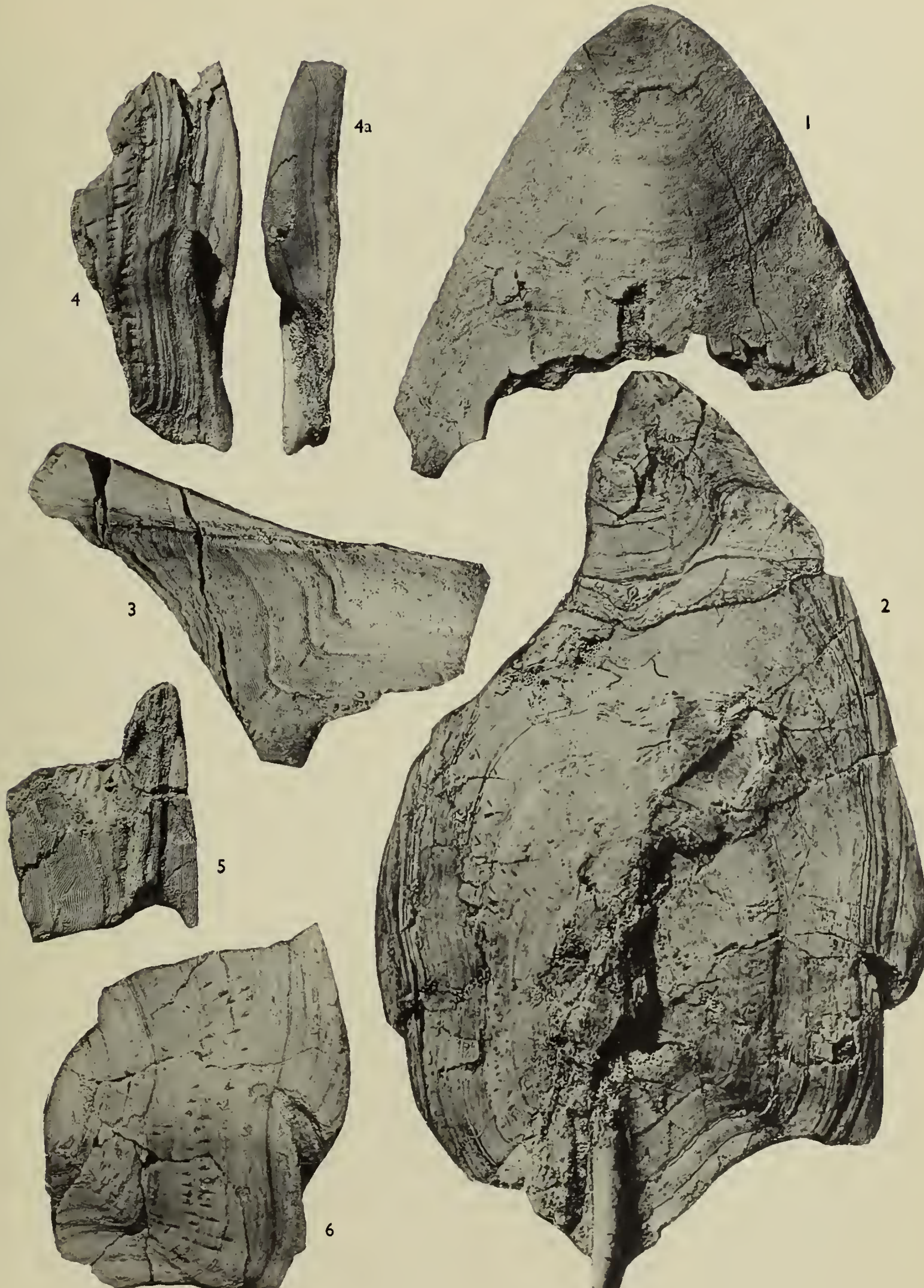
FIG. 2. Imperfect dorsal shield. Hopton Brook 4, Hopton Wafers. P.42366. × 1·5.

FIG. 3. Uncrushed posterior region of dorsal disk with dorsal spine. Upton Cresset. P.41980. ×2.

FIG. 4. Part of dorsal disk with uncrushed right branchial and cornual plates. (*a*) Lateral view. Dairy Dingle. P.33795. × 1·5.

FIG. 5. Right cornual plate with part of dorsal disk. Dairy Dingle. P.29949. × 2.

FIG. 6. Part of dorsal disk with imperfect right branchial and cornual plates. Derrington Rea Bridge. P.34341. × 1·5.



PTERASPIS

PLATE 34

Pteraspis (*Pteraspis*) *dairydinglensis* sp. nov.

FIG. 1. Rostral region. (*a*) Underside. Derrington Rea Bridge. P.32248. × 2.

FIG. 2. Undersurface of rostral region. Derrington Rea Bridge. P.32249. × 2.

FIG. 3. Rostral region. Hopton Brook 4, Hopton Wafers. P.42361. × 2.

FIG. 4. Right orbital. Derrington Rea Bridge. P.32245. × 2.

Pteraspis (*Pteraspis*) *rostrata* var. *trimpleyensis* White

FIG. 5. Undersurface of rostrum. Guildings Brook, Worcestershire. P.16477. × 2.

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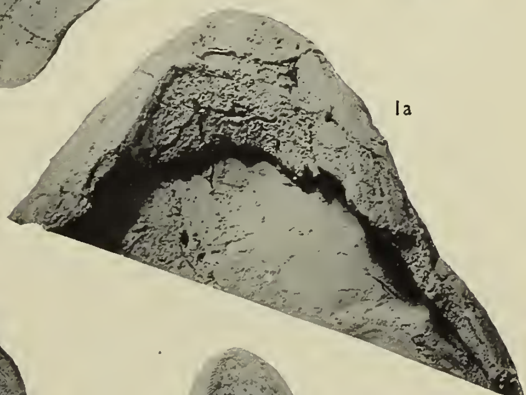

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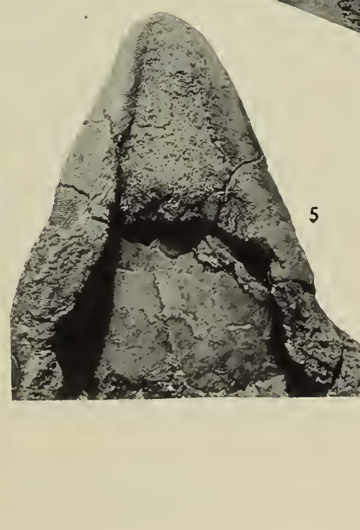

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PTERASPIS

PLATE 35

Pteraspis (*Pteraspis*) *rostrata* var. *trimpleyensis* White

Fig. 1. Rostral region. Ledwyche Brook. P.33766. × 1·5.

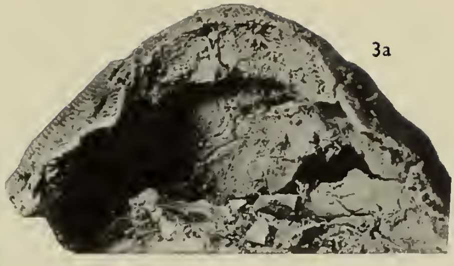
Fig. 2. Right half of small dorsal disk with dorsal spine. Oak Dingle. P.33573. × 1·5.

Pteraspis (*Simopteraspis*) *leathensis* White

Fig. 3. Imperfect dorsal shield. New Inn 1. P.34120. × 1·5. (*a*) Undersurface of rostrum.

Pteraspis (*Pteraspis*) *dairydinglensis* sp. nov.

Figs. 4, 5. Ventral disks. Dairy Dingle. P.31901, P.29918. × 1·5.



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PTERASPIS

PLATE 36

Cephalaspis bouldonensis sp. nov.

FIG. 1. Imperfect cephalic shield. The holotype. Bouldon Ford. P.43034. × 1·25.

Pteraspis (*Belgicaspis*) *crouchi* Lankester

FIG. 2. Branchial plate, anterior end missing. Heath Quarry, Bouldon. P.29853. × 2.

FIG. 3. Post-oral cover. Silvington, Waterfall. P.29844. × 4.

FIGS. 4, 5. Broad and narrow rostra from the same slab. Earnstrey Hall 1. P.27066. × 2.

FIGS. 6–8. Various shaped rostra, the first showing undersurface. Clee St. Margaret. P.32166, P.32164, P.32165. × 2.

FIGS. 9–11. Various shaped rostra. Silvington, Waterfall. P.29042. × 2; P.29830 × 2; P.29043. × 1·5.

CEPHALASPIS & PTERASPIS

PLATE 37

Pteraspis (*Pteraspis*) *dairydinglensis* sp. nov.

Oral plates. Dairy Dingle. × 4.

Fig. 1. Median plate. P.43709.

Figs. 2, 3. Near-median plates, Fig. 2 slightly imperfect basally. P.43710–11.

Figs. 4–7. Plates progressively more lateral in position. P.43712–15.

Figs. 8–11. Plates with heads broken away. Figs. 8, 11 are near-laterals with little or no overlapped areas ; Fig. 9, a left near-median plate with wide lateral and ventral overlapped areas ; Fig. 10 shows overlapped area at base only (*O*), and ornamented surface rubbed by movement against post-oral cover (*W*). P.43716–19.

a, *c*, aboral views ; *b*, *d*, oral views.

ORAL PLATES OF PTERASPIS

PLATE 38

Pteraspis (Pteraspis) dairydinglensis sp. nov.

FIGS. 1–3. Fixed lateral oral plates. P.43721–23.

FIGS. 4, 5. Anterior lateral plates. P.43730–31.

(*a*) outer ; (*b*) inner faces. All from Dairy Dingle. × 8.

PTERASPIS

PLATE 39

Pteraspis (*Pteraspis*) *dairydinglensis* sp. nov.

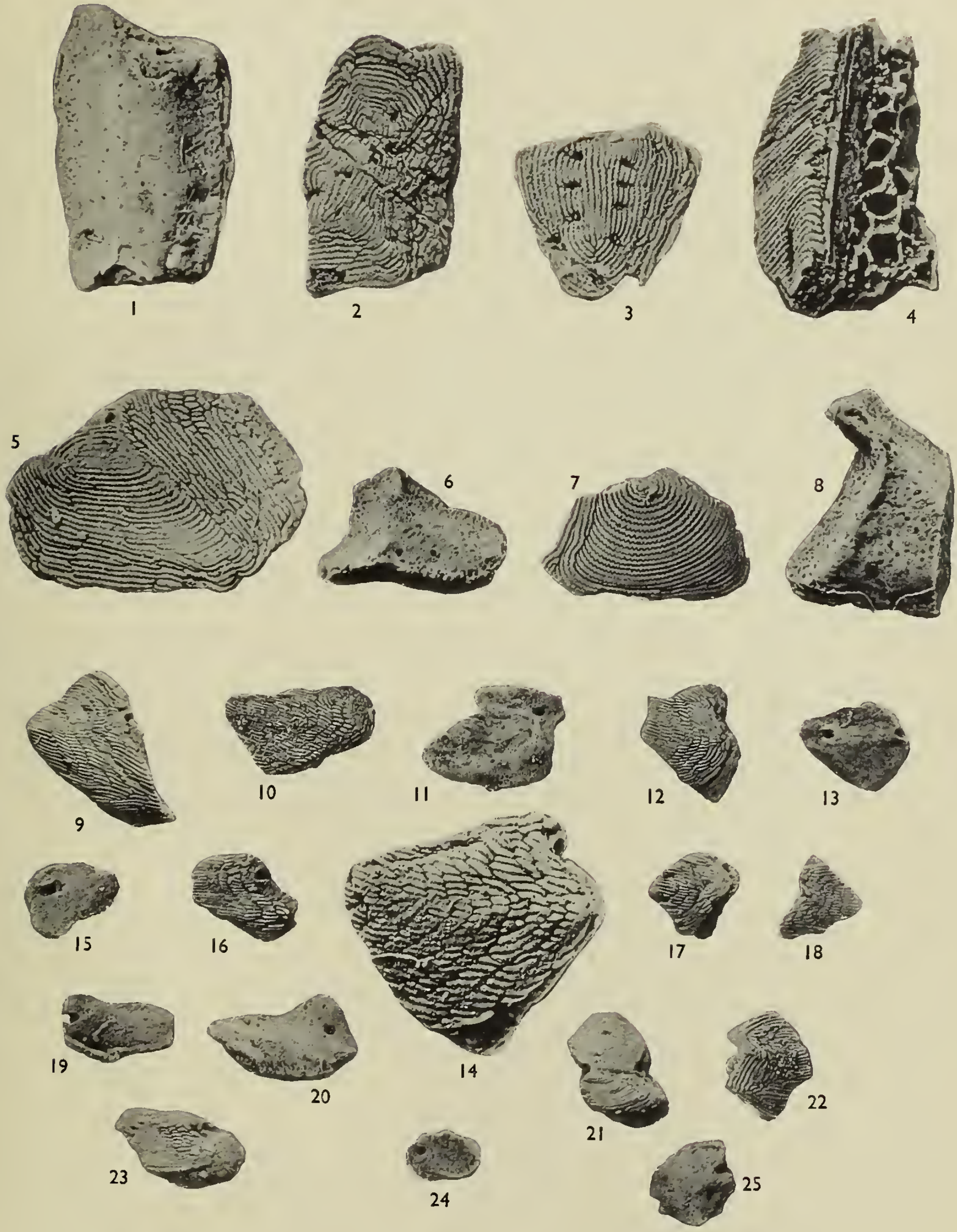
FIGS. 1–4. Posterior lateral plates. P.43700–03. × 6.

FIGS. 5–8. Post-oral covers. P.43704–07. × 6.

FIGS. 9–25. Lateral line scales. P.43601–17. × 4, except Fig. 14, × 8.

Figs. 11, 13, 15, 19, 20, 24, 25 show inner surfaces.

All from Dairy Dingle.



PTERASPIS

PLATE 40

Pteraspis (*Pteraspis*) *dairydinglensis* sp. nov.

FIGS. 1–3. Dorsal ridge-scales. (Fig. 1, inner surface.) P.43618–20.

FIG. 4. Imperfect asymmetrical ridge-scale. P.43621.

FIGS. 5, 6. Imperfect ventral ridge-scales showing signs of wear. P.43622, P.43624.

FIGS. 7–9. Posterior ridge-scales. P.43625–27.

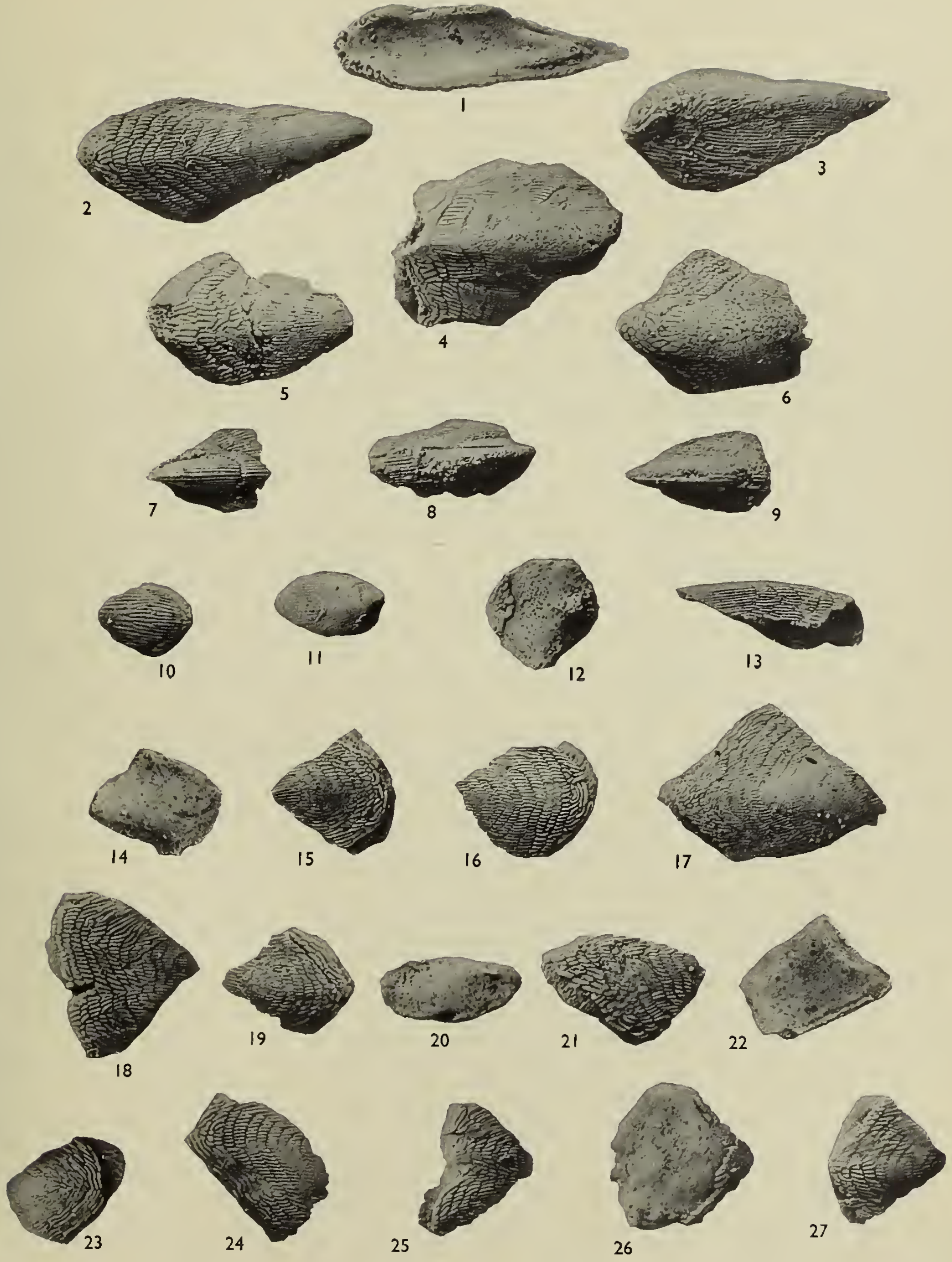
FIGS. 10, 11. Anterior ventral ridge-scales. P.43629–30.

FIG. 12. Anterior ventral ridge-scale showing ornament on undersurface. P.43631.

FIG. 13. Anterior ridge-scale of tail. P.43632.

FIGS. 14–27. Flank-scales. Figs. 14, 20, 22, 26 show undersurfaces, the last two with ornamentation. P.43633–37, P.43668–69, P.43639–40, P.43671, P.43643–46.

All from Dairy Dingle. × 4.



PTERASPIS

PLATE 41

Pteraspis (*Pterapis*) *dairydinglensis* sp. nov.

FIGS. 1–22, 24. Flank-scales. Figs. 2, 17 show undersurfaces. Dairy Dingle. P.43641–42, P.43647–56, P.43658, P.43660, P.43667, P.43676, P.43678, P.43682–83, P.43686, P.43689, P.43693, P.43692.

FIGS. 23, 25–27. Caudal scales. Fig. 27 shows the undersurface. Dairy Dingle. P.43690, P.43695, P.43694, P.43696.

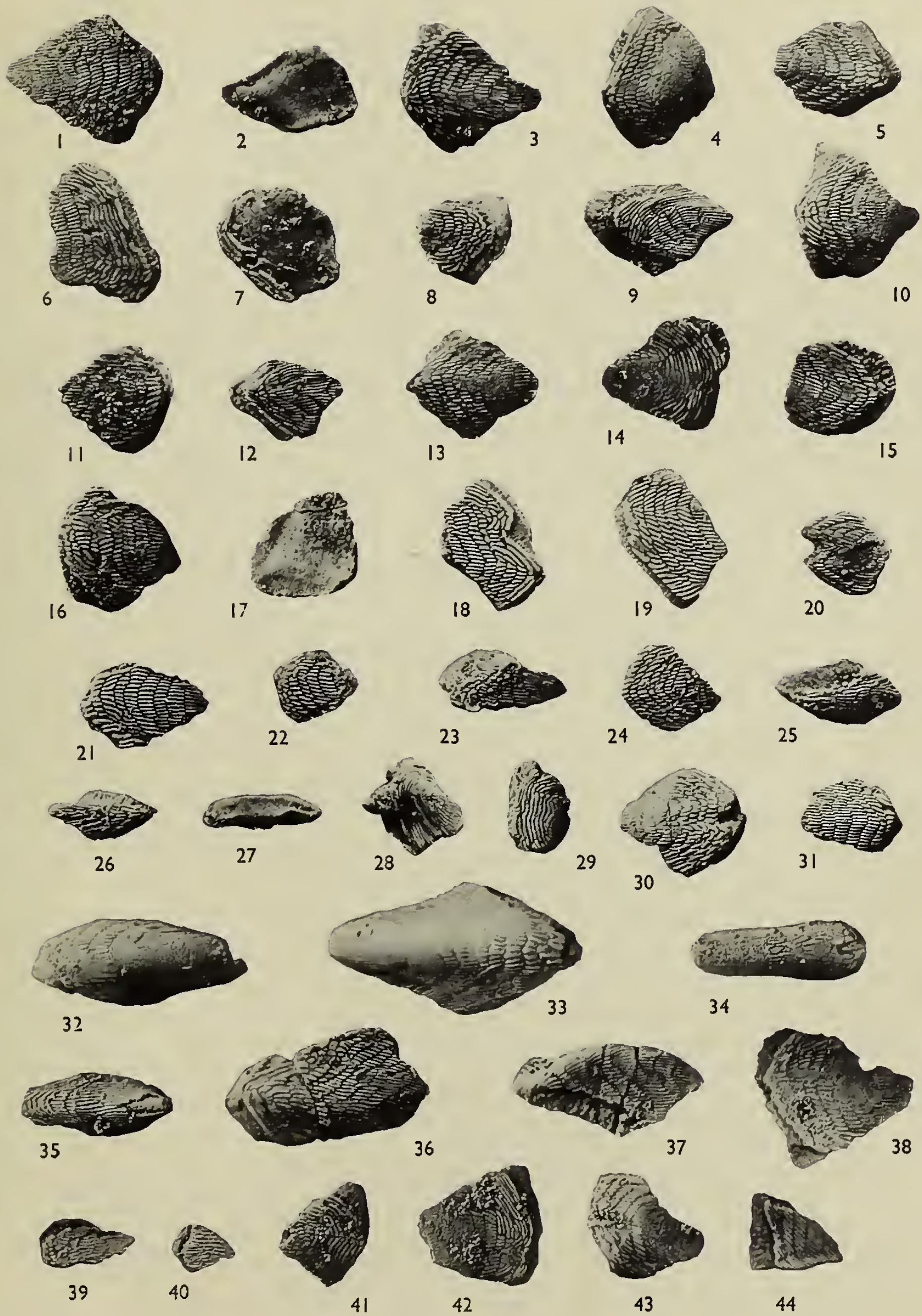
FIG. 28. Irregular scale of unknown position. Dairy Dingle. P.43698.

FIGS. 29–31. Flank-scales. Derrington Rea Bridge. P.44395, P.44398, P.44396.

FIGS. 32–37. Various ridge-scales. Upton Cresset. P.42873, P.42872, P.42874, P.42877, P.42876, P.42881.

FIGS. 38–44. Various flank-scales. Upton Cresset. P.42897, P.42893, P.42894, P.42901, P.42900, P.42904, P.42884.

All $\times$ 4.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PTERASPIS

PLATE 42

Ischnacanthus wickhami sp. nov.

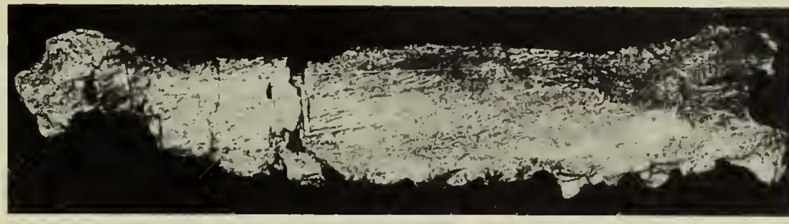
FIG. 1. Part of upper jaw with worn dentition. Man Brook 4, Trimpley, Worcestershire. P.17451. × 1·5.

FIG. 2. Part of upper jaw. *a*, Oral view. Gardener's Bank, Cleobury Mortimer. The holotype. P.24625. × 1·5.

FIG. 3. Part of upper margin of lower jaw. *a*, Oral view. Hudwick Dingle 1. P.29725. × 2·5.

Ischnacanthus kingi sp. nov.

FIG. 4. Right lower jaw. Baggeridge Colliery, South Staffordshire. P.15362. × 1·5.



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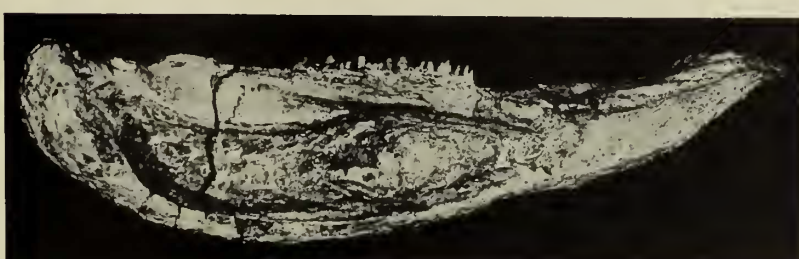


4

ISCHNACANTHUS

PLATE 43

Protaspis (*Europrotaspis*) *crenulata* sp. nov.

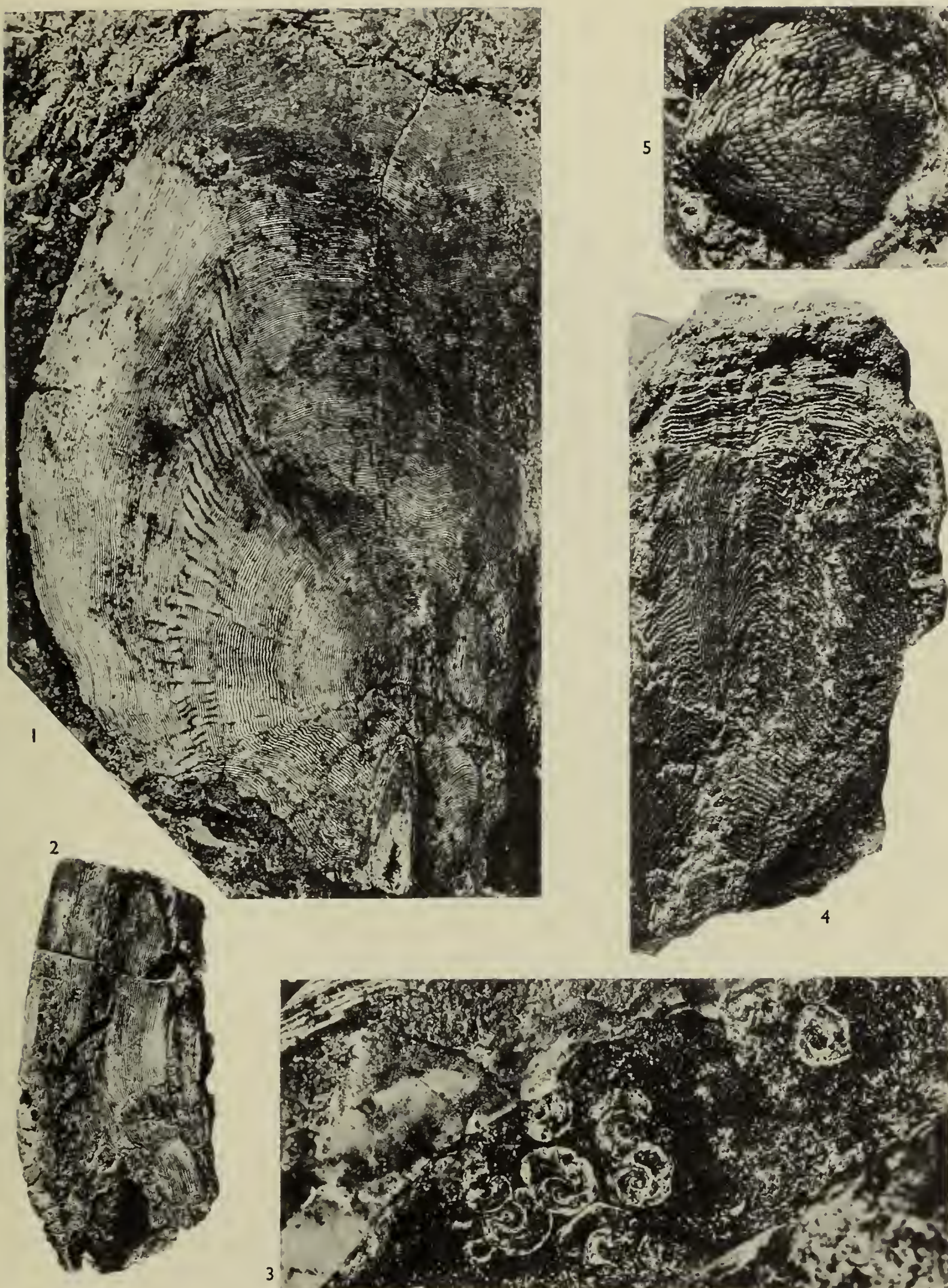
FIG. 1. Imperfect dorsal disk. Upper Overton Quarry. P.29415. × 2.

FIG. 2. Posterior end of left branchial plate with part of dorsal disk attached. Part of holotype. Besom Farm Quarry. P.28801. × 2.

FIG. 3. Part of holotype showing specimens of *Spirobis* sp. which were attached to inner surface of dorsal disk. Besom Farm Quarry. P.28801. × 7.

FIG. 4. Impression of part of dorsal disk showing discontinuous ornamentation. Besom Farm Quarry. P.28879. × 3.

FIG. 5. Flank-scale. Besom Farm Quarry. P.29068. × 8.



PROTASPIS

PLATE 44

Protaspis (*Europrotaspis*) *crenulata* sp. nov.

Fig. 1. Imperfect ventral disk, largely in impression. Besom Farm Quarry. P.26311. × 1·5.

Fig. 2. Dorsal (?) ridge-scale. Newton Dingle 2, Loughton. P.29386. × 7.

Fig. 3. (?) Ventro-lateral ridge-scale. Besom Farm Quarry. P.29077. × 8.

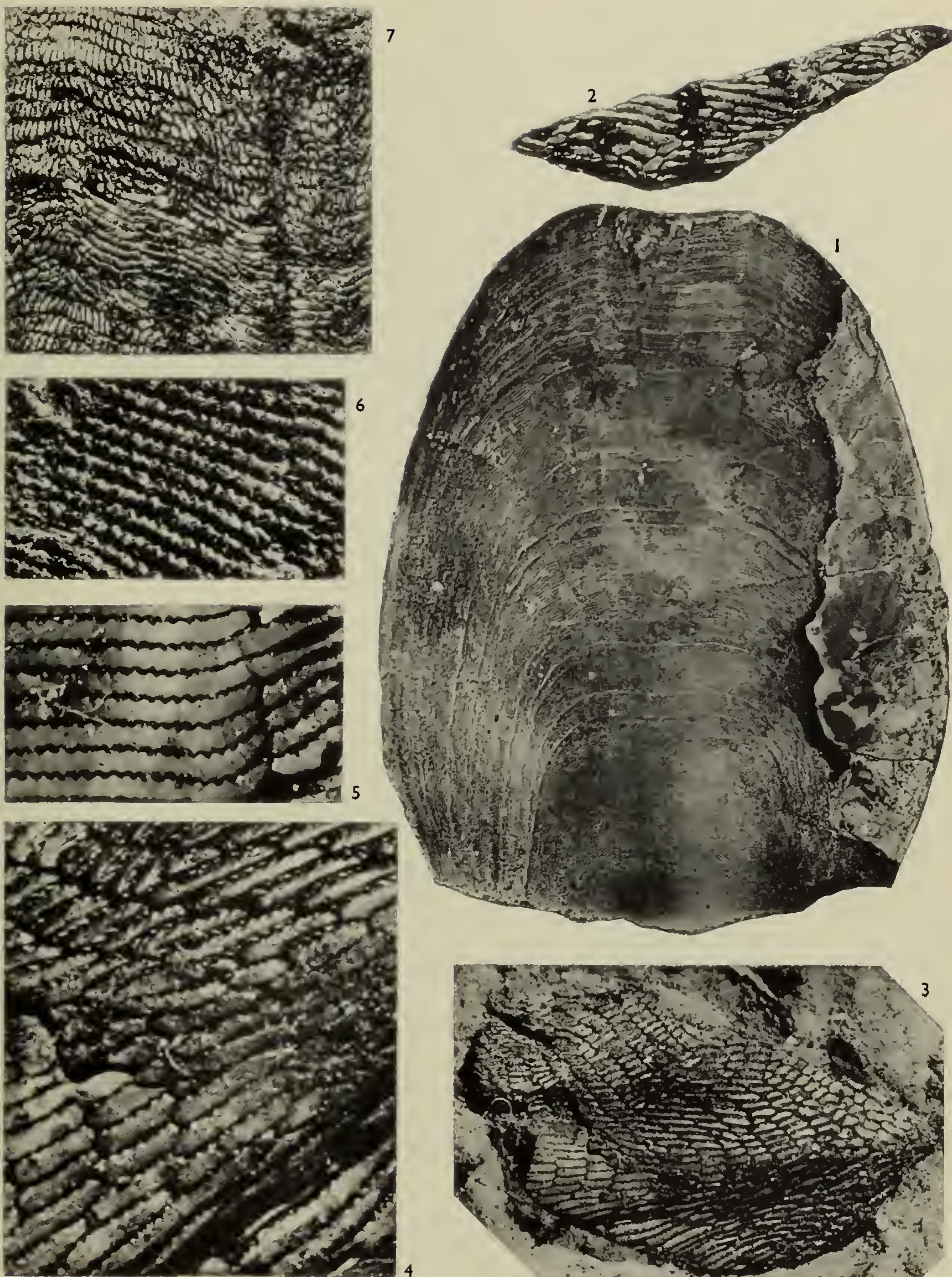
Fig. 4. Part of Fig. 3 further enlarged to show details of ornamentation. × 20.

Fig. 5. Slightly worn ornamentation on dorsal disk. Upper Overton Quarry. P.31642. × 20.

Fig. 7. Part of left anterior border of ventral disk showing irregularity of ornamentation. Besom Farm Quarry. P.29479. × 5.

Protaspis (*Europrotaspis*) *arnelli* Brotzen

Fig. 6. Ornament of dorsal disk. Stage IIIb. Kujdanow, Podolia. (N.H.M. Stockholm P.106.) × 20.



PROTASPIS

PLATE 45

Fig. 1. *Pteraspis* (*Cymripteraspis*) *leachi* White. Flank-scale. Swanlake Bay, Pembrokeshire. P.29329. × 8.

Fig. 2. *Pteraspis* (*Cymripteraspis*) *leachi* White. Flank-scale. Prescott Reaside. P.29261. × 8.

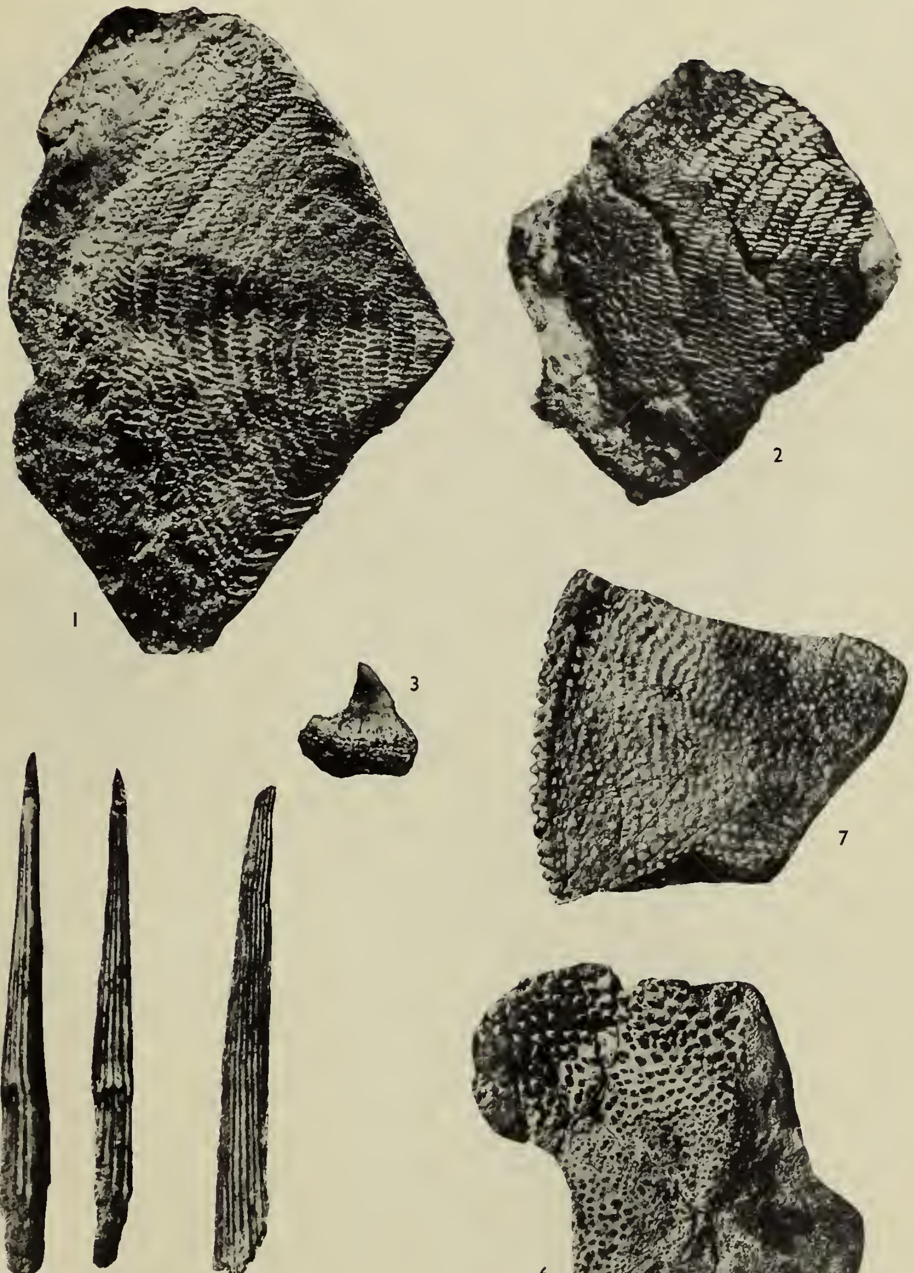
Fig. 3. Tooth of Acanthodian. Besom Farm Quarry. P.28903. × 5.

Fig. 4. *Ischnacanthus* (?) *anglicus* sp. nov. Median fin-spine with restored dorsal view. (*a*) Right side view. The holotype. Besom Farm Quarry. P.29082. × 3.

Fig. 5. *Onchus wheathillensis* sp. nov. Median fin-spine. The holotype. Besom Farm Quarry. P.29083. × 3.

Fig. 6. *Overtonaspis billballi* gen. et sp. nov. Right anterior lateral plate. The holotype. Upper Overton Quarry. P.29272. × 1·5.

Fig. 7. *Kujdanowiaspis anglica* (Traquair). Imperfect right anterior ventro-lateral plate. New House Farm, Neenton. P.29821. × 1·5.



PTERASPIS, ACANTHODIANS and ARTHRODIRES

PLATE 46

FIG. 1. *Kujdanowiaspis willsi* sp. nov. Left spinal plate, dorsal view. The holotype. Besom Farm Quarry. P.28913. × 5.

FIG. 2. *Kujdanowiaspis willsi* sp. nov. Left central plate, referred to this species. Besom Farm Quarry. P.28889. × 3.

FIG. 3. *Prescottaspis dineleyi* gen. et sp. nov. Median scute. Prescott Reaside. P.29267. × 7.

FIG. 4. *? Prescottaspis dineleyi* gen. et sp. nov. Left posterior ventro-lateral plate without surface ornamentation, possibly of this species. Prescott Reaside. P.29259. × 3.

FIG. 5. *Wheathillaspis wickhamkingi* gen. et sp. nov. Imperfect anterior ventro-lateral and spinal plates. The holotype. Besom Farm Quarry. P.28908. × 4.

FIG. 6. Lateral scale of an arctolepid. Upper Overton Quarry. P.29756. × 3.

ARTHRODIRES

PLATE 47

Pseudosauripterus anglicus (A. S. Woodward)

FIG. 1. Cast of right entopterygoid, oral view. Church Quarry, Farlow. P.27176. × 1·5.

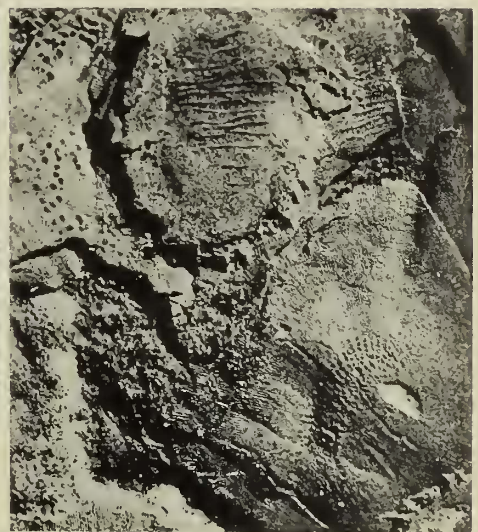
FIGS. 2–4. External impressions of scales of paratype block, with light reversed to give positive effect. Church Quarry, Farlow. P.200*a*. × 2.

FIG. 5. External impressions of scales on counterpart of type-block, with lighting reversed. Scale on right is the underside of that figured by A. S. Woodward, 1891, pl. 16, fig. 6. Church Quarry, Farlow. P.7601. × 2.

1

2

3



4

5

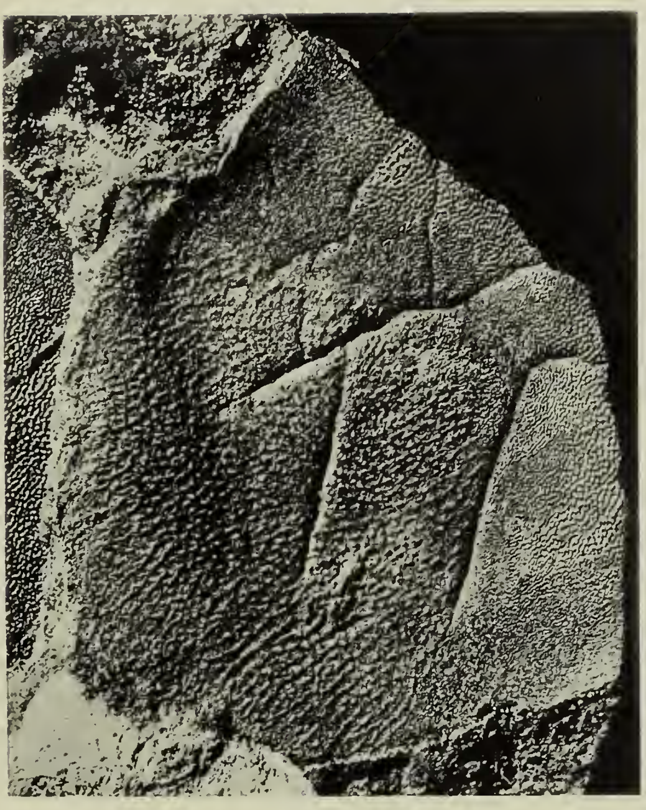
PSEUDOSAURIPTERUS

PLATE 48

Sauripteris taylori Hall

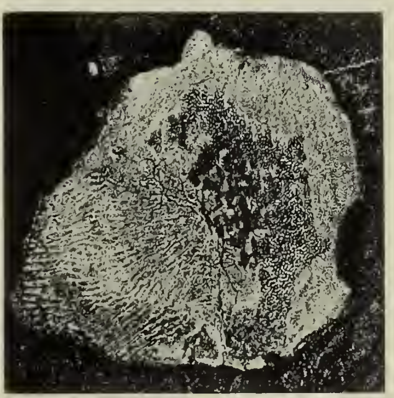
FIG. 1. External impression of scale with lighting reversed to give positive effect. The cracks are of *post-mortem* origin. Blossburg Red Beds, Cassadaga Stage, lower Upper Devonian, near Blossburg, Tioga County, Pennsylvania. P.43518. × 2.

FIGS. 2, 3. Scales from same slab as Fig. 1. Nat. size.



1

2



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SAURIPTERIS